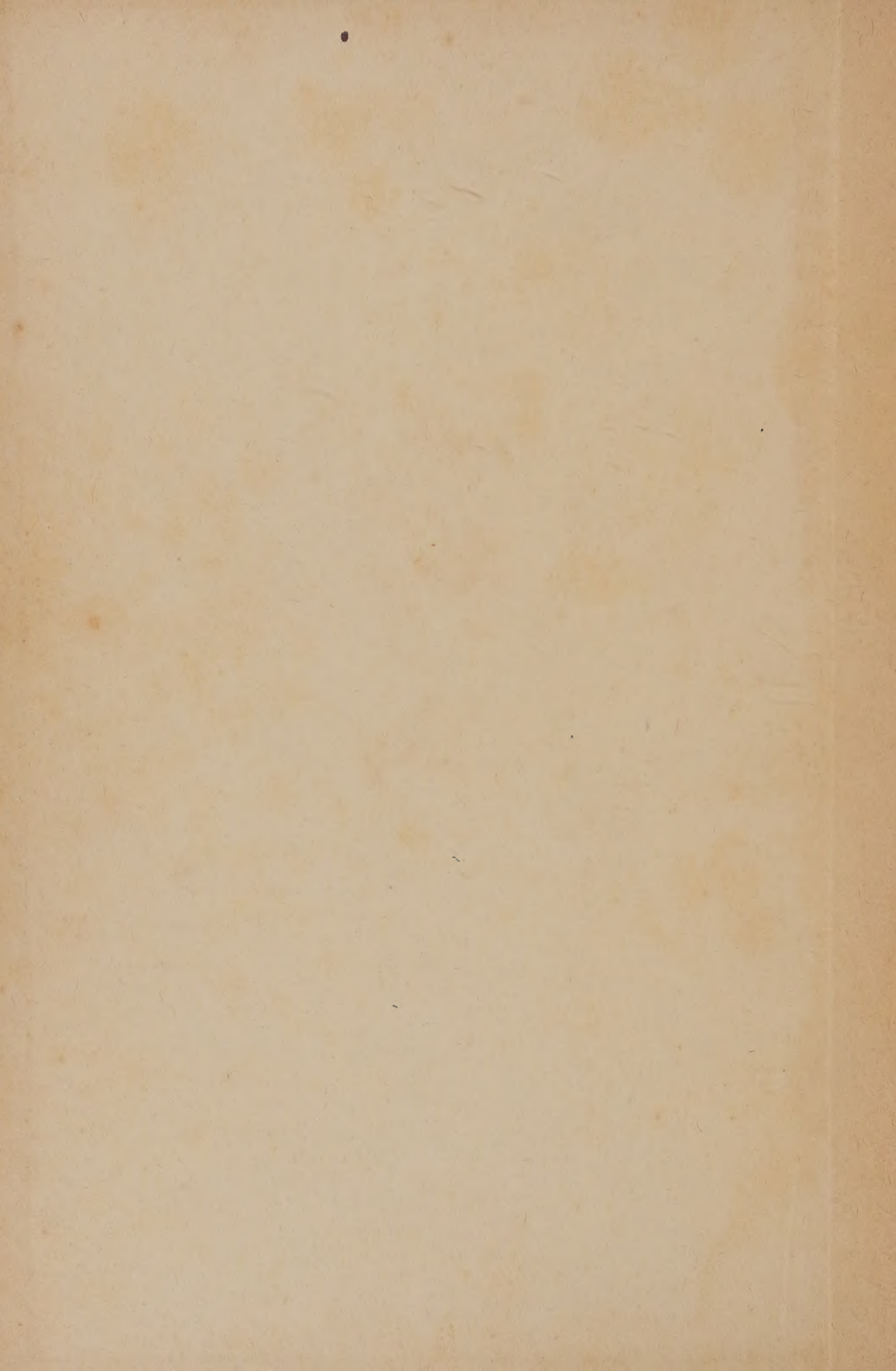




THE DESERT TRAVELERS WATCH THE PERIL OF THE DUST GO BY



Dust, raised in storms, flung high from volcanoes, scoured incessantly from the dry earth by lusty winds, plays a part in hygiene and in optics that is only beginning to be understood. This picture is reproduced by permission of Robert Arnot from M. L. Granger's "Escaped from the Peril".

The Book of POPULAR SCIENCE

The Wonders of Modern Discovery
The Triumphs of Inventive Genius
The Story of all Created Things and
the World They Live In

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VOLUME

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SOME ENEMIES OF PLANT LIFE

Parasitic fungi, bacteria, slime-
molds, algæ and flowering plants

DISEASES WHICH THESE ORGANISMS CAUSE

IN the present chapter we propose to discuss in a general way those organisms which occur upon plants as parasites, and which cause disease, manifested in various ways. It does not lie within our province to treat of insects and the injury which many of these do to plants, nor to discuss the various types of depredations made on plant life by higher animals and man. We must, moreover, refrain from enumerating or describing the injuries which plants in nature suffer from the ravages of fire, wind, hail, lightning, excessive heat and cold and other physical agents.

Foremost among the organisms which cause disease in plants must be named the fungi. To this group belong the molds that form on fruit and bread, the mushrooms, toadstools and puffballs which occur in lawns, meadows and woods; the shelving or bracket fungi which are often found on decaying trees or stumps; the mildews, rusts and smuts which attack vegetables, cereals and fruits; the bird's-nest fungi; the stink-horn fungi; the earth-stars; and many other interesting forms.

Although many fungi are parasites, causing disease in plants or more rarely in animals, there are many others which live a wholly saprophytic existence and have never been known to cause disease. Saprophytic fungi occur on the ground or on decaying logs or other refuse material. They obtain their nutriment from the dead and disorganized remains of other plants or animals, and when found in the soil use the humus for their food. Parasitic fungi obtain their food from the plant or animal upon which they normally occur, and this parasitized organism is called "the host".

None of the fungi are able to live a wholly independent existence. This is due to the fact that they lack the green coloring matter, chlorophyll, which enables all the higher plants in the presence of sunlight to elaborate their own complex food materials from the carbon dioxide of the air and water. Fungi can, in fact, grow luxuriantly in the total absence of sunlight and carbon dioxide. Mushrooms are grown for the market in total darkness in old abandoned coal mines, caves and cellars.

Fungi are of many kinds. We are particularly interested in the parasitic forms, but in order that we may better understand these it will prove advantageous to select a common saprophyte for preliminary discussion. We will use for this purpose the very common bread mold, *Rhizopus nigricans*. This fungus occurs throughout the whole world and is a familiar sight to housekeepers everywhere. It grows easily at ordinary temperatures, and occurs particularly on substances of a starchy or sugary nature, such as damp bread, paste, preserved fruit and rotting potatoes. The moldy growth, which in many cases is so profuse that a cottony mat results, is made up of an enormous number of extremely fine threads or filaments which branch repeatedly and ramify the substratum in every direction. If examined with a magnifying glass of even a very low power these threads may be plainly seen, and the whole mat resembles a tangled skein of white twine. These threads constitute the vegetative portion of the fungus and are termed mycelium. The branches which penetrate the food substance obtain the nutriment for the whole fungus body.

How the spores of the fungus bread mold are widely disseminated

Shooting upward into the air from the mass of mycelium may be seen a number of vertical threads, the sporangiophores. Each of these at its apex is swollen out into a globose head called the "sporangium". These sporangia to the unaided eye appear as minute black or brown dots. The sporangium is a hollow sac which bears within a very large number of exceedingly minute rounded bodies called "spores". These spores are analogous to the seeds of higher plants, and are blown by the wind for long distances. They serve to disseminate the fungus, and are able to survive great extremes of heat and cold and will remain alive for a long time in very dry places, such as the dust of the city street. When they fall upon damp bread or some other favorable substance they germinate by sending out a little cylindrical thread called a germ-tube. This grows rapidly in length and branches and soon the white mat of mycelium is developed. The mycelium again develops sporangia and spores, and the life cycle of the fungus is completed. It will be seen that the fungus is of a very simple type.

So cosmopolitan is this fungus in its distribution and so common are its spores in nature that all kinds of starchy and sugary foodstuffs and fruits must be protected in one way or another from contamination by it. For this reason oranges, grapefruit, lemons and apples are commonly wrapped in tissue paper when packed for the market; and since this and other common molds are not able to enter and damage these fruits until after they have been bruised or otherwise injured there is the additional incentive also for careful handling. Fruit which is in any manner bruised permits the entrance of the spores of *Rhizopus nigricans* and other common and equally destructive molds. After the entrance of the germ-tube from the spore, the mycelium develops rapidly and a condition of rotteness is produced. Strawberries which have been picked for the market are particularly susceptible to attack by the bread mold; sweet potatoes also suffer greatly from it.

A very simple experiment and one which can be carried out in any home will convince the reader that these molds are everywhere. If a piece of bread be first soaked in water, and then placed in some receptacle where it will remain undisturbed it will be evident in a very few days that it already contained or had come in contact with spores of probably more than one species of mold. Moldy growths will appear over its surface and the small black dots demonstrating the presence of sporangia of *Rhizopus nigricans* will be prominent. If blue-green spots develop these are due to the presence of another mold, *Penicillium*, which is extremely common and especially destructive on fruit in storage. A single microscopic spore will on germination produce a colony or mat of fungous mycelium of considerable extent in a few days.

Why one often sees mold on the surface of canned fruit even carefully put up

If canned fruit is not sealed while hot, fungous spores may fall on its surface and a moldy growth result. In fact since certain fungous spores are very resistant to the killing action of heat the ordinary methods of sterilization used in the average kitchen often fail to rid the fruit of all the spores. This fact explains the development of mold on the surface of fruit in cans which have been carefully handled. Some fungous spores and certain bacteria in the spore condition will resist a temperature as high as that of boiling water. Fruit or vegetables sterilized with "live" steam (under pressure) in an autoclave will, however, be rid of all viable spores, and moldy growths will not develop.

This brief survey of the life-history and activities of the common bread mold will enable us to understand more clearly the nature of those fungi which cause disease in plants. Before fungi had been carefully studied by botanists, agriculturists in general believed that the rusts on cereals, mildews on fruits, and other similar fungi were manifestations of a diseased condition inherent in the plant. They did not even dream that these evidences of disease were actually microorganisms, and the cause rather than the effect of the malady.

FIGHTING SOME OF THE ENEMIES OF PLANT LIFE



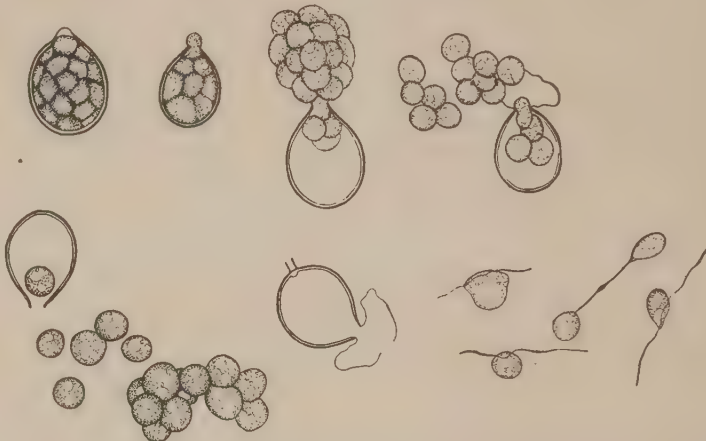
A dusting machine being used in making an application of sulphur to the leaves and fruit of a large apple orchard. The practice of dusting with sulphur is to an extent supplanting the use of sprays.



Treating oats with formalin to prevent loose smut. This treatment insures a clean crop.

Since then a vast amount of work has been done on the study of fungi. There are thousands of species in this group, no two are exactly alike, and hundreds of them are parasites. The various diseases on the host plants are due to different organisms, only a single fungus being concerned in a given disease. Thus rose mildew is caused by one fungus, grape mildew by another and potato mildew by still another. The differences in the fungi concerned are evident not only in differences in morphology (form and structure) but also from the fact that any parasitic fungus, if placed upon a host plant other than its own, will refuse to infect it. Some fungi do, however, attack several different hosts.

The hosts in such cases are usually closely related; for example, several species of rose are attacked by one mildew. Some parasitic fungi which resemble each other so closely in their morphology that



The conidia of *Phytophthora infestans*, cause of "late blight" of potato, germinating to form ciliated zoöspores which later come to rest, lose their cilia, round up, put out a germ tube, and infect the host. (After Rosenbaum.)

they cannot be separated on structural characters have wholly different host plants. Such forms are termed biologic species. There are other fungi which under ordinary conditions live as saprophytes, that in the presence of certain favorable environmental factors assume the parasitic mode of life and attack living plants. These are called "facultative parasites". Others normally parasites may become saprophytes in certain cases. Many fungi which are called parasites live for only a portion of their life-cycle on the living tissue of the host, and complete their existence, often undergoing considerable growth, as saprophytes. Relatively few are obligate parasites, forced to pass their entire life in the host, refusing to develop in artificial culture media.

We will now select for discussion several of the more interesting plant diseases caused by fungi, and will call attention to the important differences in the fungi concerned. The condition known as "damping off" in seedlings and young plants may well be chosen to illustrate the nature of diseases caused under certain environmental conditions by facultative parasites. Although several fungi under favorable conditions will cause the phenomenon of damping off the organism usually concerned is *Pythium debaryanum*. Every gardener, amateur or professional, has, at some time or other, had the disappointing experience of finding a large number of seedlings in the seed-bed beginning to wither and die

in patches soon after their appearance above ground. This takes place especially when the seed-bed has been placed in a dark or shaded spot and given too liberal a supply of water. Damping off

occurs frequently in growing mustard and cress, where the plants usually stand closely crowded. The first symptom of disease is the tendency of some of the plants to bend over at a sharp angle and shrivel up. A close examination reveals the fact that this collapse of the plant is due to the rotting of one side of the stem near the surface of the ground. After the disease has obtained a foothold in a crowded seed-bed it spreads with great rapidity from a central point in all directions, and if allowed to run its course will gradually kill off all the seedlings. If the soil of such an infested seed-bed is used again for growing seedlings the second crop will be infected, and so on for any number of successive crops. It is evident that the causal organism remains in the soil for a long time.

ONLY MONUMENT IN THE WORLD TO AN INSECT



MONUMENT TO THE MEXICAN COTTON-BOLL WEEVIL, ENTERPRISE, COFFEE COUNTY, ALABAMA

Before the invasion of the boll weevil in 1915 the average cotton crop of this county was about 35,000 bales. The yield was cut the first year to 60% of normal and, in spite of the use of every conceivable means to exterminate the pest, to 10,000 bales the second year and to 3000 the third. Realizing that something had to be done and that quickly, diversification of crops was tried with the happiest results. Peanuts, corn, hay, sweet potatoes and sugar cane were grown, the yield of the first-named breaking the world's record for area involved and cash return — over five million dollars — and hogs and cattle were raised and shipped in trainload lots. Enterprise, one of the county seats, is surrounded by small farms of from 50 to 250 acres each owned by 1500 thrifty farmers with pretty homes. The inscription on the base of the monument reads:

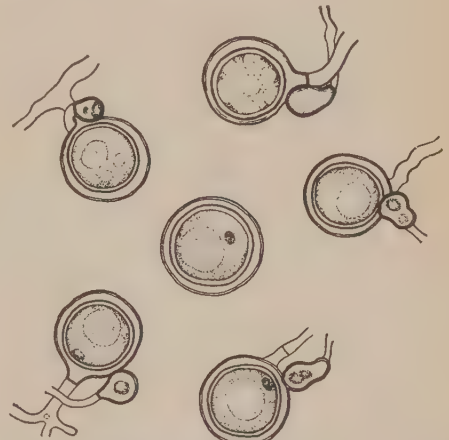
"In profound appreciation of the boll weevil and what it has done as herald of prosperity this monument is erected by the citizens of Enterprise, Alabama, December 11, 1919."

To examine this organism select a diseased plant, section it through the diseased spot on the stem and place the tissue under a compound microscope. We shall find that the plant is permeated with the mycelial threads of the fungus. In the beginning the fungus is restricted to the interior of the host plant, but later, having gained a foothold here, it sends its hyphæ out into the air and by coming into direct contact with neighboring undiseased plants soon spreads throughout the bed. Due to the closely packed condition of the seedlings in the bed, this is easily accomplished. As the seedlings wither and fall over they become entangled with surrounding healthy plants, and the fungus is enabled to pass rapidly from one plant to another.

An examination of the hyphæ of the fungus under the microscope discloses the presence of several different sorts of spores. Asexual spores or conidia are cut off from the mycelium, and appear as large, globose or oval bodies. These germinate by a germ-tube. Other similar structures, the sporangia, when placed in a drop of water permit the escape of their protoplasmic contents in the form of small ciliated motile spores. These swim about and after coming to rest produce infection. The conidia and sporangia except in their methods of germination resemble each other very closely. They are produced on aerial hyphæ outside the plant. Another type of spore is formed within the host tissue. Here on one of the endophytic hyphæ a small clavate or club-shaped lateral branch arises and comes into close contact with another similar branch of a more globose form. The clavate branch is the male reproductive organ, antheridium, the globose branch the female organ, oogonium. The contents of the male cell pass into the female and fertilize it. Then all of the protoplasm in the female cell rounds up into a spherical ball and assumes a heavy cellulose wall. This ball is the sexual spore or oöspore. It functions as a resting spore, and will remain in the old dead stems of the host plant or in the soil for months, and under favorable environmental conditions will then germinate.

These sexual spores serve to carry the fungus over the winter in the soil, and it is by their germination that successive crops of seedlings year after year are infected. The asexual spores (sporangia and conidia) function in the spread of the disease from plant to plant or from seed-bed to seed-bed during the growing season.

Damping off may be eliminated or greatly reduced by giving attention to the methods of culture. The seed should not be sown thickly and little water should be used on the seed-bed. Allowance should also be made for the penetration of plenty of air and sunlight. If in spite of these precautions the disease is troublesome the soil should be sterilized. This can be success-



Oögonia, antheridia and oöspores of such a fungus as the "damping-off" organism *Pythium debaryanum*. These resting spores are thick-walled and resist the cold of winter.

fully accomplished with steam under pressure. A large zinc or galvanized iron pan should be inverted over the bed and its edges forced down several inches into the soil. Steam should then be led into this from a pipe. The steam will penetrate the soil for several inches and effect sterilization. Formalin, more easily applied, is also frequently used in soil sterilization.

Another fungus of great economic interest on account of its bearing upon the food supply of man is *Phytophthora infestans*. This organism causes the well-known and much dreaded "late blight" of potatoes. In its morphology this fungus is very similar to the damping off organism, *Pythium debaryanum*, and is classified in the same subgroup of the fungi, the *Phycomycetes*.

Loss to potato growers from late blight

It apparently does not, however, produce sexual spores in nature, although certain investigators claim to have developed them by growing this fungus on certain kinds of artificial culture media, of which oat-juice agar is the best known. There are a large number of diseases of the potato caused by different organisms, but late blight is the most destructive. This disease takes an annual toll of thousands of dollars from growers. Several times in history it has caused potato famines of wide extent. The Irish potato famine of 1845 was a national calamity and in 1875 the disease in England was so disastrous that the government called upon the greatest authority, Anton De Bary, for help in combating it. He studied the organism carefully and made certain recommendations for controlling the disease, but there are points concerning the life history of the fungus which are not fully understood even today.

What happens when late blight strikes the potato crop

The disease is called "late blight" to distinguish it from a less serious disease, "early blight" due to another fungus, *Alternaria Solani*, which usually attacks the potato earlier in the summer. The first symptoms of late blight may be observed upon the leaves of the plant in midsummer. The leaves lose their brilliant green hue and become mottled with dark opaque spots having a water-soaked appearance. These spots are indefinite in outline and later turn brown or even black. The affected portion of the leaf dies. On the under surface of these patches on the leaf, particularly at the margin of the spot, may be seen a white, frost-like mildew. This growth is made up of a large number of sporangiophores and sporangia which arise from the stomates of the leaf from endophytic mycelium. The sporangia are blown by the wind to other plants where they germinate during rain, forming swarm spores which infect the new host. Some sporangia fall to the ground, germinate there in the soil water, and produce swarm spores which infect the young tubers.

The disease spreads rapidly through a field, particularly in wet weather, and its daily advance from a central point of infection may be easily watched. The swarm spores which enter the tuber develop there into mycelium; and a definite sunken spot on the surface of the tuber and a reddish-brown rot in the interior soon proclaim the presence of the organism. The mycelium winters in the tuber in storage in a dormant resistant condition, and renewed growth takes place the following spring when these tubers are placed in the moist ground. When the tuber sprouts and the young plant begins to develop, the mycelium either grows up the young stem from the tuber causing general infection in all parts of the plant or it grows to the outside of the tuber and produces sporangia over its surface in the soil. These sporangia may then be washed to the surface of the ground in the heavy spring rains, or they may be brought up by worms or by the plow in cultivation. They then easily infect the lower leaves of the plant which in heavy rains beat against the ground.

When leaves are killed or diseased smaller potatoes are the result

The mycelium of the fungus spreads rapidly in the leaves of the plant, and gives off enzymes which kill the cells of the host for a considerable distance beyond its own advance. This fact explains the rapid formation of large dead areas in the leaves. When weather conditions are unfavorable for the fungus the lesions on the leaf increase very little in extent and the disease is less destructive. The importance of the malady to the potato crop lies in the fact that when the leaves are killed or diseased, smaller tubers than normal are developed. The leaves of any green plant manufacture carbohydrate food, and in the case of the potato this is transferred to the roots and is stored there in the form of starch in large tubers as reserve food. Naturally when the leaves fail to produce this carbohydrate material, smaller tubers develop. Moreover in extremely severe cases the plant is killed. Often the entire crop of tubers is disfigured, rotted and unmarketable.

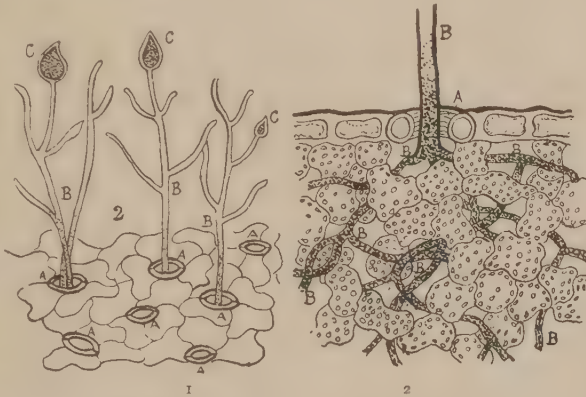
Experiments have demonstrated that some varieties of potatoes are much less susceptible to infection by this fungus than are others, and when possible these varieties should be grown. Growers who raise potatoes on a large commercial scale find it wise to spray their plants with Bordeaux mixture, and smaller growers might well follow their example. Bordeaux mixture should be applied at the 5-5-50 strength (5 lbs. copper sulphate, 5 lbs. quicklime, 50 gallons of water) and should be sprayed on the plants five to eight times during the summer beginning when the plants are six inches high and continuing throughout the growing season. Late spraying on late-maturing varieties is especially necessary. The difference in the crop clearly warrants the expense. Late blight also occurs to a lesser extent on tomatoes and certain other less important plants.

Other diseases of the potato of note are common scab, black leg, powdery scab, black wart, dry rot, leaf roll, tip burn, etc. The black wart disease is particularly destructive and has caused great losses in Europe. Our federal quarantine laws forbid the importation of this disease into the United States, but it has made its appearance in a few places.

The application of any substance as a fungicide is in the case of most diseases merely a preventive measure. In the case of Bordeaux mixture the salts of copper on the leaf serve as a protection, since copper is a poison and will kill the young germ-tubes or swarm spores before they are enabled to infect the host. After the entrance of the fungus into the plant fungicides do no good. Other methods of control such as the cutting out of diseased parts may prove effective.

Some plant diseases do not seem to be susceptible of control. One of these is the chestnut blight which in recent years has come into great prominence. This disease, caused by the fungus *Endothia parasitica*, made its first appearance in this country several years ago in the chestnut trees of Long Island. Its origin is a mystery. It is a very virulent parasite and soon kills the host by girdling the main branches and trunk. The mycelium of this fungus bears little flask-shaped fruiting bodies called perithecia in which the spores are developed in sacs called asci. Each ascus contains eight spores. These perithecia protrude from the bark of the tree and the spores are ex-

uded in countless numbers. In a very few years all of the chestnuts on Long Island have been killed outright, and the disease has spread up the Hudson and into New England and Pennsylvania. Although thousands of dollars have been spent in studying the disease and the organism which causes it, no method of control has been

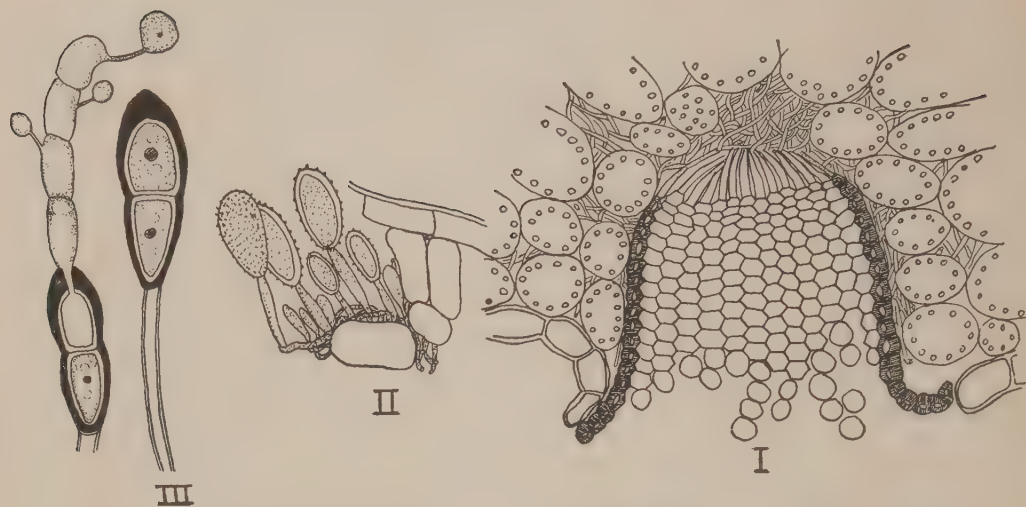


THE LATE BLIGHT POTATO DISEASE

1. Highly magnified portion of under surface of potato leaf showing filaments (B) of *Phytophthora infestans* protruding through stomata (A) and bearing sporangia (C). 2. Highly magnified section of potato leaf showing filaments of *Phytophthora infestans* penetrating the tissues of the leaf. In doing this they absorb the nutriment in the cells.

found. Birds carry the spores of the fungus on their feet for long distances and would cross any cutting-out isolating barrier.

Another disease of great importance has recently appeared on the white pine in this country. It was imported from Germany on nursery stock of white pine and if it assumes as serious proportions here as abroad it will be one of the most destructive diseases in our forests. This fungus has two different hosts and alternates in its life-cycle from one to the other. Such a fungus is called "heteroecious". In this species one stage of the fungus appears on the leaves of the currant bush and the other occurs on the twigs or limbs of the white pine. One suggested measure of control consists in the total destruc-



THE VARIOUS SPORE FORMS OF *PUCCINIA GRAMINIS*, THE CAUSE OF WHEAT RUST

I. The cluster cup on the under side of the leaf of barberry, showing the development of aecidiospores in chains. These spores infect the wheat plant.

II. The thin-walled uredospores developed on the wheat leaves during the summer. The masses of these spores in the pustules on the host present the red appearance characteristic of the rust.

III. The thick-walled teleutospores which are developed on the wheat stems or stubble in late autumn. These are the resting spores which hibernate. In the spring they germinate and produce a four-celled tube, the promycelium, on each cell of which a thin-walled spherical spore is borne. These spores are the sporidia. They are blown to the barberry and infect it.

tion of all the wild and cultivated currant bushes in the endeavor to eliminate one of the essential stages in the life history of the fungus. Infection of pines must in every case come from spores developed on the currant, and infection of the currant from spores developed on white pine. The fungus has received the name "white pine blister rust" from the characteristic blisters developed on the bark of the pine. The state of New York is endeavoring to combat the disease in its white pine nurseries and forests. The causal organism, *Cronartium ribicola*, is a member of a large group of fungi known as the rusts. Many of these are heteroecious, and many cause serious diseases of very considerable economic importance.

The rusts on cereals are well known. The common wheat rust, *Puccinia graminis*, passes part of its life cycle in the leaves and fruit of the barberry, a bush much used for ornamental hedges. Spores developed here later blow to the young wheat plants and infect them. The leaves and stem of the wheat soon show yellow rust-like pustules, and it is this stage of the fungus which gave rise to the name rust. In the autumn black pustules appear on the stem of the wheat and the spores contained in these,

the teleutospores, are thick-walled, resting spores which enable the organism to live through the winter. These spores in the spring germinate and infect the barberry. Wheat fields affected with rust lose their healthy green color and produce smaller heads of grain. Other closely related species of rust attack rye, oats, barley, timothy and various wild grasses. The rusts as a group are very destructive, and in the aggregate reduce the value of crops in this country alone by millions of dollars a year.

The smuts are close relatives of the rusts. They produce a black, sooty mass of spores on the host, usually in the floral parts. The loose smut of oats, *Ustilago avenae*, can be seen in almost any field of oats during the summer and will be recognized by the black powdery mass of spores in the heads of the grain. Each spore in this mass is a tiny, thick-walled, spiny, sphere. The spores are easily blown about by the wind and fall upon undiseased plants throughout the field. Many of them become attached to the seeds, and remain firmly applied to the outer seed-coats throughout the winter in the bins in a wholly dormant condition. When the seed are planted in the spring the spores

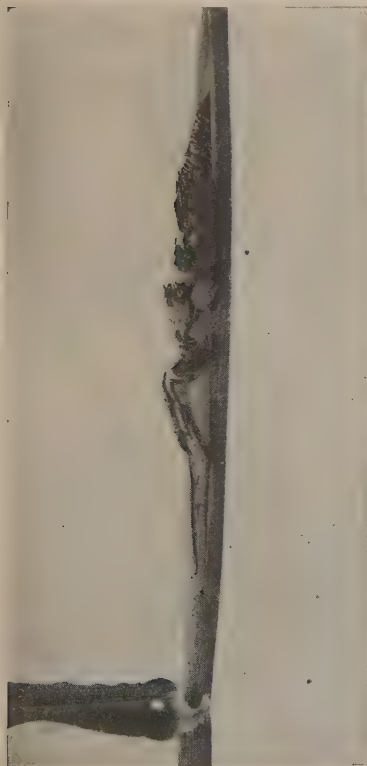
RUSTS AND SMUTS THAT BLIGHT PLANTS



The white pine blister rust, showing the typical pustules of rust spores.



Wheat smut. The head of grain to the left is normal, the others badly smutted. The causal organism is *Ustilago tritici*.



Oat smut. The causal organism is *Ustilago avenae*.



Fire blight of apple due to *Bacillus amylovorus*. A badly blighted and blackened twig contrasted with a healthy one.

germinate and infect the seedlings, forming in them a mycelium which grows upward through the developing plant and produces the mass of spores in the head at maturity. The spore masses replace the ovaries and other floral parts.

Oat smut may be prevented by treating the seed before planting with a solution of formalin made by diluting one pint of the commercial solution with fifty gallons of water. The oats should be placed on a clean barn floor, and the formalin should be sprinkled over them as they are being shoveled over. One gallon of this solution should be used for one bushel of seed. The oats must be mixed thoroughly, then shoveled into a pile and covered with canvas. After standing in the pile for four hours the oats if they are to be drilled must be spread out and allowed to dry. They can be sown by hand without drying. One extra peck for each bushel should be allowed to offset the swelling of the grain.

Other species of smut attack wheat, corn, barley, rye and other cereals. The life-cycles of different species of smut show essential differences, and the control measures recommended vary in consequence. The common loose smut of wheat passes the winter in the mycelial condition inside the wheat grain rather than as a spore on its surface. For this reason treatment with formalin is of no avail since a solution strong enough to penetrate the grain and kill the fungus would also kill the germ of the wheat. It has been found, however, that seed may be treated successfully with hot water at 54° C. (129.2° F.) for ten minutes; the fungus mycelium will be killed but the more resistant wheat germ will still live. It is necessary in the use of this method of treatment to give the seed a preliminary soaking for about six hours in cool water at ordinary room temperature. This starts the mycelium of the fungus into renewed growth and renders it easier to kill than in the dormant condition. The wheat seed should be placed in small loose sacks or wire baskets not holding over one-half peck each. It is of great importance that the seed be treated in small lots in order that all the grain may be quickly brought to the temperature of the water. In attempting to use

large lots the grain at the center remains cool longer and receives an insufficient treatment, while a longer treatment than that recommended may kill the grain. The hot water method of seed treatment is not easy to use but when the directions are carefully followed good results are obtained.¹

Other smuts require other treatments. Corn smut cannot be controlled by any type of seed treatment since the fungus hibernates in the soil.

The bacteria known to all of us as the cause of many diseases in animals and man are also the cause of diseases of plants. In fact there are many more plant diseases due to bacteria than there are animal diseases due to these minute organisms. Bacteria parasitic on plants cause characteristic diseases. In many of these pronounced wilting or blighting of the foliage takes place, and to these manifestations the names "bacterial blight" and "bacterial wilt" are commonly applied. In other cases soft rots of various plant parts, such as the fruit, roots and tubers, takes place. More rarely woody galls or corky excrescences are formed.

The "fire blight" disease of apple, pear and quince, caused by *Bacillus amylovorus*, is one of the best known bacterial diseases of plants. In this instance the bacteria are disseminated by bees, flies and other insects, and the disease cannot be controlled by spraying. The twigs are killed and the leaves blacken and die but do not fall from the tree. This results in the blackened appearance of the foliage of the tree which has given rise to the name "fire blight". This is a difficult disease to control, and a diseased tree can only be saved by prompt cutting out of all infected twigs or limbs. Even these drastic methods frequently fail, and in some sections of the country where climatic conditions favor the rapid development of the disease, pears or quinces cannot be satisfactorily grown. The disease on apples is somewhat less destructive.

¹ Either of the following bulletins will give all the detailed information necessary.

Bulletin 152, Bureau Plant Industry, U. S. Dept. of Agriculture, Washington, D. C.

Bulletin 283, Cornell University Agricultural Experiment Station, Ithaca, N. Y.

The organism causing crown gall in plants occurs upon a wide variety of hosts. The disease produced manifests itself in the development of large galls on various parts of the plant. Since these frequently occur at the base of the stem near the ground at the crown of the plant the name "crown gall" has been applied. These galls in many respects resemble cancer, and the careful study of this disease may prove of value in connection with the study of this dread scourge of man. Investigators have produced large galls by artificial infection on beet, raspberry, tomato and many other hosts.

Other plant diseases caused by bacteria which are worthy of mention are the black rot of cabbage, the soft rot of carrot and certain other vegetables, the streak disease of the sweet pea, the soft rot of the hyacinth, bean blight and the wilt of cucumber and muskmelon.

The group of organisms known as the "slime molds" are very low in the scale of life; so low in fact that in one stage of their existence they live as naked masses of protoplasm, called "plasmodia". In this state they infest solid food material like an amoeba and move about with a streaming motion. They seem to lie on the border line between plants and animals and cannot be certainly said to be either. The great majority of the species are saprophytes occurring on old logs, stumps, sawdust piles, rotting leaves, etc., but a few species are parasites of considerable economic importance.

The club root of cabbage is caused by a slime mold, *Plasmiodiophora brassicæ*. This is the most serious disease of cabbage with which growers have to contend. The roots are greatly hypertrophied and deformed, and soon crack open. Decay organisms then gain an entrance, and the root becomes putrid and foul smelling. The normal development of small roots is retarded, and the plant above ground failing to obtain a normal supply of food from the soil is stunted. The leaves are underdeveloped and a head is not formed. The parasite lives in the soil for a number of years, and land which has once produced a diseased crop should be avoided for cabbage, cauli-

flower and other related plants. Manure containing cabbage refuse should not be used, and crop rotation if practised must avoid the repetition of cabbage on infested land within five years. Only healthy plants should be set out. If the use of infested land is imperative then a good quality of stone lime should be applied evenly over the land at the rate of three tons to the acre, and this application should be made eighteen months before planting. An acid soil favors the development of the parasite.

Another slime mold disease of importance is the powdery scab of potato caused by *Spongospora solani*. This disease is easily recognized by the little pustules filled with brown powder which are formed over the surface of the tuber. This powder is a mass of the spores of the organism. This disease is very destructive and infected areas should be quarantined. It is not yet a serious menace in this country. Only clean tubers should be planted.

Few of the algae are parasites, but a common disease of the tea plant called red-rust is due to a member of this group.

Of the parasitic flowering plants mistletoe and dodder are the best known representatives. Mistletoe occurs as a parasite on trees, and dodder is a serious pest in fields of alfalfa and clover. In each case the parasite sends large haustoria or suckers into the tissue of the host plant and thus obtains its food. Alfalfa fields attacked by dodder show the plants dying in small more or less circular areas. In these areas the ground is covered with a tangled mat of yellow threads of the diameter of heavy twine. These are the dodder stems. These threads wind about the host plants, send in haustoria and soon kill them. Infested spots should be mowed closely. Then the stubble should be sprinkled with kerosene, covered with dry hay and burned. In planting alfalfa and clover only seed free from dodder seed should be used. The seed can be cleaned by sifting it with a sieve made of No. 34 wire, with twenty wires to the inch. Any state agricultural experiment station will analyze free any seed sent to them. All inquiries regarding plant diseases should be addressed to the plant pathologist.

PIGEONS IN FLIGHT AND AT REST



© Ewing Galloway, N. Y.

FLOCK OF PIGEONS IN FLIGHT AT SAN DIEGO



Photo Ewing Galloway, N. Y.

FEEDING THE PIGEONS ON BOSTON COMMON

OUR COMMON BIRDS IV

Doves and Pigeons, Cuckoos, and
Wood and Water Kingfishers

GENTLE DOVES AND CRESTED KINGFISHERS

THERE is no real difference between doves and pigeons. "Dove" is ordinarily applied to the smaller species but often the two words are used interchangeably.

In general, pigeons and doves (family *Columbidæ*) can be distinguished from other birds by their small heads, heavy bodies and compact plumage. They have slender bills which are swollen at the tip and covered at the base by a soft fleshy skin called a "cere". Their wings are long and pointed, but their legs are relatively short, so that while they are extremely strong fliers, they walk with short mincing steps. Their tails are always well developed and may be either square or rounded at the tip. Often the name "pigeon" is restricted to the square-tailed and that of "dove" to birds with rounded or pointed tails, but this is by no means constant, the passenger pigeon, for example, having a decidedly pointed tail.

There are about six hundred and fifty species of pigeons and they are found in all parts of the world except arctic and antarctic regions, being most abundant in the tropics, especially in and about the Malay Archipelago, where possibly they may have originated. Because of their defenselessness they are particularly adapted to island life where enemies are few. This may account for their great abundance in the Polynesian Islands and also for the brilliant and conspicuous plumage of many of these island species, reds, greens and purples occurring in wonderful combination, in contrast to the majority of continental species which are bluish or brownish.

Isolation likewise accounts for such anomalous pigeons as the extinct dodo and solitaire of Mauritius and Pedriguez. These curious, heavy-bodied birds had entirely lost the power of flight because of the absence of terrestrial enemies on the islands which they inhabited. This made them an easy prey for the first explorers, causing their early extermination.

In size, pigeons vary from the tiny ground doves, some of which are smaller than sparrows, to the crowned pigeons which measure from two to nearly three feet in length, or the extinct dodo which was described by its discoverers as "bigger than our swans". They vary also greatly in habits, and in the choice of their haunts. Some species live in large flocks, while others are solitary; some inhabit the dense forests, others the open plains; some are terrestrial and rarely fly, while others are arboreal and among the strongest fliers. Most species disband during the nesting season but the passenger pigeon, now extinct, nested in colonies of immense size.

The nests are crude affairs, built of sticks, with little shape and no lining. The eggs are pure white and usually two in number. The young are naked when hatched and perfectly helpless. They are fed by regurgitation during the entire time they are in the nest, and indeed until they learn to eat by themselves. The food of the parents consists largely of seeds or grain which is stored in an extremely large, two-lobed crop, and there softened and partially digested. This curdlike mass, mixed with a secretion from the wall of the crop and called "pigeons' milk", is injected into the throat of the young bird.

In drinking, pigeons differ from other birds in that they do not raise the head in order to swallow but keep the bill immersed until the draught is finished.

Of the true pigeons, the domestic variety is naturally the best known. The parent species is the rock dove which, in the wild state, inhabits the rocky coasts of Europe from the Faroes to the Cyclades, nesting in caverns. In the domestic state, it has been carried to all parts of the world and more than one hundred and fifty different kinds which breed true are now recognized by fanciers. In the United States, the only surviving species of true pigeon is the band-tailed pigeon of the Rocky Mountain region, and it is becoming rare in many places. It is a bird nearly the size of the domestic pigeon and somewhat the same color, but with a white band on the back



Photo W. C. Herman

THE LAST OF THE PASSENGER PIGEONS

of the neck and a light gray band on the end of the tail. It feeds largely upon acorns, young sycamore balls and wild berries and normally confines itself to the mountains, although sometimes, if food is abundant, it frequents larger river bottoms in large flocks.

If we omit the white-crowned pigeon of the Florida Keys and the West Indies, the only other true pigeon indigenous to the United States and Canada was the passenger pigeon, now extinct. The vast flocks which during the last century darkened the sky for hours or even days at a time, are no more. The last survivor of the whole race died in the Cincinnati zoölogical park, September 1, 1914. Rewards of several thousands of dollars have since failed to bring to light a single living specimen of this splendid bird.

Alexander Wilson, writing about 1808, estimated that a flock observed by him near Frankport, Kentucky, numbered over two billions; and a nesting colony near Shelbyville, in the same state, extended through the woods for nearly forty miles and was several miles in width, every tree of suitable size being loaded down with nests, the larger trees containing from ten to forty. Their nocturnal roosts, at other seasons of the year, were nearly as impressive. Nuttall in describing them states: "Nothing can exceed the waste and desolation of the nocturnal resorts; the vegetation becomes buried by their excrement to the depth of several inches. The tall trees for thousands of acres are completely killed, and the ground completely strewn with massive branches torn down by the clustering weight of the birds which have rested upon them. The whole region for several years presents a continued scene of devastation, as if swept by the resistless blast of a whirlwind." The last wild birds of which we have any definite record were shot on September 14, 1898, one in Michigan and one in New York.

During the ninety years from the time Wilson wrote until the species disappeared the birds were netted and shot by the thousands and shipped in carloads or even train loads to the markets or fed to the hogs. Not content with netting and shooting, the market hunters went to the nesting grounds with clubs and fires and sulphur pots and killed the birds on their nests. At one nesting place in Michigan, five hundred netters were at work and their average catch was 200,000 birds each, and at another it was estimated that fully a billion birds were accounted for. The laws, at that time, gave them no protection because, as stated in some of them, it was considered that they were so numerous that the inroads of man could have no appreciable effect upon their numbers. And now they are gone. The last nesting known in New York state occurred near Olean in 1868, in Michigan in 1881. Perhaps, we may learn from the mistakes of our fathers and, though we have lost this species, we may yet save others that are following it to extinction.

The mourning dove, though it is put in a different family or sub-family, appears like a small edition of the passenger pigeon. Indeed, when the rewards were offered for the discovery of a passenger pigeon, numerous claims for it were made by non-observant persons who had discovered mourning doves.

The notes of most wild pigeons are soft cooing sounds and those of the mourning dove are even more gentle and mournful than others. This has given rise to its name.

The turtle dove, a species that is often seen in captivity in this country, is native throughout Europe during the summer, retiring to northern Africa for the winter. It is quite similar to our mourning dove, being fawn color but with a larger black mark on the sides of the neck.

The cuckoos

To one interested in the habits of birds, the members of the cuckoo family (*Cuculidæ*) present some of the strangest paradoxes of all nature. Constancy and maternal devotion, symbolic of bird life, are with some of the species replaced by promiscuity and parasitism; and the privacy of nest life, for which most birds risk the hardships and dangers of long migrations, is forsaken by some cuckoos for a communal habit. The majority of Old World species, for example, build no nests of their own but lay their eggs in the nests of other birds, where they are hatched and the young brought up by the foster parent. The New World species called anis, on the other hand, build a common nest in which several families lay their eggs and then share the duties of incubation. A few cuckoos, and among them the common American species, do not depart widely from the common habit of birds, for they build nests and raise their own young.

There are about one hundred and ninety species in the cuckoo family, found all over the world, though most abundant in the tropics. About thirty-five species are found in the New World but only two of these are common north of Mexico, the black-billed and the yellow-billed species. The road runner, however, which is fairly

common in some parts of the arid Southwest, likewise belongs to this family. The California cuckoo is but a larger representative of the yellow-billed species, and the mangrove and Maynard's cuckoos and the anis are tropical species that occasionally wander to our Gulf Coast.



MOURNING DOVE AT ITS NEST WITH YOUNG

In general, cuckoos are medium-sized, dull brown, gray or black birds, although there are some exceptions among the African golden, and the violet and emerald cuckoos, which are beautifully iridescent. Almost as strange as their parasitic habit is the simulation by many species of



NEST AND EGGS OF MOURNING DOVE

cuckoos, of the plumage of the smaller hawks or of the birds which they parasitize. Thus the common European cuckoo and the hawk cuckoos of Asia resemble so closely the common small sparrow hawk as to alarm all small birds by their approach. The drongo cuckoos of India,

on the other hand, resemble the drongo shrikes, which they parasitize, even to the extent of having the outer tail feathers curved outward, both birds being uniformly black.

The cuckoos are rather low in the scale of bird life, lying between the parrots and kingfishers. Even a superficial examination shows their difference from ordinary perching birds, because, instead of having three toes directed forward and one backward, there are two forward and two backward, as in the parrots and woodpeckers.

Unlike the young parrots, the cuckoos do not pass through a downy stage but are almost naked when hatched, being extremely ugly black-skinned little creatures with a bare scattering of threadlike feathers. The growing feathers remain in their sheaths until fully developed so that for a long time their bodies seem incased in tiny lead pencils. When the feathers are fully developed, the quills burst open at about the same time so that the change from the curiously mailed creatures to the light fluffy fledglings takes place in a very few hours.

The common cuckoo of Europe, and there are about a dozen very similar species, ranging through Europe and Asia except Polynesia, are about ten or twelve inches long, brown or gray above and barred below, with long fan-like tails and pointed wings that give them a swift, hawk-like flight. As a result, they have been much persecuted by gunners and game-keepers so that they have become very wary and are seldom seen even where their notes are a familiar sound.

The notes of the common European cuckoo, so familiar to everyone because of the old-fashioned clocks of that name, are always associated with the coming of spring, for the cuckoos are migratory, spending the winter in Africa and returning to Europe among the first of the spring birds. For this reason, in spite of its parasitic habits, it has become a great favorite. Thus Wordsworth writes:

"O blithe new-comer, I have heard,
I hear thee and rejoice.
O Cuckoo, shall I call thee Bird,
Or but a wandering voice?"

The birds parasitized by the cuckoo include most of the species smaller than itself whose nests it is about to discover. Apparently the egg is not laid directly in the nest, for many reliable observers record having seen the cuckoo deposit its egg on the ground and then carry it in its bill to the selected nest. The eggs of the cuckoo are small for the size of the bird, but larger than those of the host. They vary in color from a dull greenish to a dull reddish-gray with spots and mottlings of darker shade. Some authorities claim that the color of the eggs is hereditary and that a cuckoo always parasitizes the species in whose nest it was raised and whose eggs its eggs most closely resemble. Other authorities disagree, however, and there is as yet no proof one way or the other.

However that may be, no sentiment is wasted either by the old cuckoo or by the young, for once the egg is laid, the old bird never comes back to it, and when it has been hatched by the foster parent the young cuckoo works the rightful young or unhatched eggs on to his hollowed back and heaves them overboard. The parasitized birds, except for some outcry at the first appearance of the cuckoo, once the egg is laid, never seem to realize the calamity that has befallen their own young but take pride in filling the cavernous mouth of the young stranger.

In the New World cuckoos the parasitic habit is not developed, although all species are rather shiftless nest builders and occasionally drop their eggs in each other's nests or, very rarely, in the nests of other birds. Thus in the accompanying photograph of the nest of a black-billed cuckoo, the larger egg is one of the yellow-billed species. Another evidence of a possible former parasitic habit among the American cuckoos, or a leaning in that direction, is that the eggs are not always laid at regular periods, one each day, as with normal birds. Intervals of several days sometimes elapse and a nest may even contain young birds and fresh eggs. The eggs are pale greenish blue, those of the black-billed species being smaller and darker.

The parasitic habit of the Old World cuckoos, however, is developed in the New World in a totally unrelated family, the *Icteridæ* or blackbirds. In this family, the majority of species are expert nest builders and show all the constancy and parental instincts of normal birds, but one rather large division, the genus of cowbirds (*Molothrus*) has departed so far that, with one exception, the habits of its members are similar to those of the European cuckoo. There is this difference, however, that the eggs are laid directly in the nest of the smaller bird.

The American black-billed and yellow-billed cuckoos are very similar in general appearance, being long slender birds, dark brown above and pure white beneath.



NEST OF BLACK-BILLED CUCKOO



YOUNG BLACK-BILLED CUCKOOS IN THE NEST

The nest with eggs contains one of the yellow-billed and three of the black-billed cuckoo.

The long tail feathers bear white spots at the tip, those of the yellow-billed species being more conspicuous. This and the yellow lower mandible, together with the red eye ring of the black-billed species, are the most distinctive differentiating marks.

The cuckoos frequent open woodlands or the borders of woods, and sometimes come into orchards and gardens, where they are of inestimable value because of their fondness for tent caterpillars and other hairy larvæ that are so destructive to foliage and that, when full grown, are shunned by most birds. They are usually shy, retiring birds and are very easily overlooked because of their habit of remaining absolutely quiet when alarmed.

In flying from tree to tree, they have a graceful sweeping flight, though they seldom fly long distances through the open. In keeping with their retiring habit, their migrations, which carry them to South America, are performed entirely at night.

The notes of the two species are so similar that one cannot always distinguish between them. The song of the yellow-billed species has been represented by Dr. Chapman as: tut-tut, tut-tut, tut-tut, cl-uck-cl-uck, cl-uck-cl-uck, cl-uck, cow, cow, cow, cow, cow, cow. The song of the black-billed species is somewhat softer and the cow-cow notes are not usually run together. The last part of the song is quite similar to that of the mourning dove, and indeed the bird is quite dove-

like in many ways. A curious superstition declares that their songs predict rain, and this has given them the name of "rain crows" in many parts of the country.

The anis, which have been mentioned as having a communal habit, are among the most familiar sights of the West Indies or of the open land and clearings of tropical America where they are known as "savanna blackbirds" or "tick birds". They are typically pasture birds where they sun themselves with wings half spread on the tops of bushes or follow the cattle, catching the insects which they disturb in the grass or pecking the ticks from their backs. There are three species of anis, all of them uniformly black with some metallic reflections and with large com-

pressed bills that give them a curious parrot-like profile. In other ways, however, they are far from parrot-like. They are weak fliers and their long tails are composed of but eight feathers, the smallest number which any bird possesses.

When the nesting season arrives, each company commences building a nest, usually in the top of a small tree. It is a bulky affair, about the size of a crow's nest, made of sticks and green leaves. In it the various females lay their eggs, and if there is not enough room for all the eggs, green leaves are placed over the first layer and the rest of the eggs are laid on top. The lower ones usually do not hatch and the upper ones are sometimes laid at such different intervals that fresh eggs and young birds are found in the same nest. The exact apportionment of duties between the females has not yet been discovered, but it is believed that they all help in incubating and in feeding the young.

Another curious and entertaining bird of the cuckoo family is the road runner, or "snake killer", of Mexico and the arid regions of our Southwest. It is sandy-brown in color, broadly streaked, and nearly half of its two feet in length is taken up by its enormously developed tail. Its long legs permit it, without the use of its wings, to cover the ground about as fast as a horse can trot. In fact it never flies unless hard pressed but often darts out into the road in front of a horse and easily keeps ahead until it gets tired out, when it disappears into the brush, throwing its long tail over its back to act as a brake.

In food habits, the road runner is omnivorous, eating caterpillars, beetles, cactus fruits, horned toads, lizards, snakes and young birds with equal avidity. Many wonderful stories are told of its strange ways with rattlesnakes, and surely its curious appearance is sufficient for any number of strange yarns. One has it that when a road runner discovers a rattlesnake coiled up asleep, it builds a corral of thorny twigs about it and then drops one upon the snake to awaken it. The startled snake thrashes about in its effort to escape, fills its body full of thorns and soon falls prey to the road runner.

Its nesting habits are quite normal, for it usually builds a rough nest of twigs in a thorny bush and lays from four to nine white eggs. Sometimes it utilizes the deserted nest of another bird. The young birds are easily tamed and make fine pets, seeming to become attached to their captors.

In general, cuckoos, even the parasitic species, are valuable birds because of their great capacity for destructive caterpillars, and it is unfortunate that superstition or popular prejudice is against them. In Europe, there is a belief that they transform into hawks in the winter, and nearly everyone shoots them on sight. In this country, our species suffer less and are fully guarded by our laws but many ignorant persons still shoot them.

The kingfishers

Whether sitting patiently on a branch overhanging the water or dashing up the stream with a wild rattling cry, the kingfisher always demands attention. His curious shape, due to his large crested head, long bill and short tail, his striking coloration, his interesting habits and the natural charm of his habitat, all combine to make him one of our most attractive and best-known birds. It is the same the world over. The members of the kingfisher family (*Alcedinidæ*), of which there are nearly two hundred species, are beloved by all people. It is little wonder that many legends have grown up about them. The Halcyon Days of Greek mythology, for example, were the fourteen days in winter when Æolus, the god of the winds, kept the weather calm so that the floating nest of the kingfisher could ride safely over the sea. The birds themselves were Ceyx and Alcyone, the latter the daughter of Æolus, whom Zeus had changed into kingfishers. In the days of Shakespeare the dried body of a kingfisher was supposed to keep moths from woolen garments or, if suspended from the ceiling, to point its bill in the direction of the wind.

While the kingfishers are almost all brilliantly colored, they are not all alike in habits but are divided into two natural groups, the wood-kingfishers and the water-kingfishers. The former frequent

woodlands, open country, or even gardens, where they feed upon insects; crustaceans, frogs, lizards, sometimes small birds and mammals, and only occasionally take fish. The latter group, like our American bird, frequent streams and lake shores and feed almost entirely upon fish, although frogs, crayfish and aquatic insects are sometimes taken. The majority of the woodkingfishers are extremely brilliant, metallic greens and blues, satiny whites, russets or reds predominating. One genus of about twenty species, found in India and the Malay Archipelago, have elongated central tail feathers which are enlarged at the tip, or racquet-shaped. One of the largest and best-known species, however, is much duller. This is the famous laughing jackass of Australia and New Guinea, a bird nearly as large as a crow but having a much heavier bill. It is brown above and grayish white below, this color extending around the neck and in a broad band over the eye. A little greenish blue on the lower back and in the wing enlivens the otherwise plain attire.

The name is derived from its loud gurgling, laughing note which sounds "as if a troop of fiends were shouting, whooping and laughing" about one. It is a tame, stupid bird and rather inquisitive, coming about camping parties and watching all that transpires with apparent interest.

The common kingfisher of Europe, and the only one found in the British Isles, is one of the water-kingfishers with habits much like our American bird. It is much smaller, however, only seven inches long,

and more striking, being bright azure-blue above and rusty orange-red beneath. It is considered the most brilliant of the British birds.

All kingfishers nest in holes, mostly in perpendicular banks of streams, but some species nest in walls, trees or stumps, and all lay pure white eggs. Usually no nest is built, although sometimes a few straws or bones of the fish which they have eaten cover the floor of the cavity.

Young kingfishers are naked when hatched, lacking even the sparse down which is characteristic of most young birds. They likewise omit the juvenile plumage, for the first feathers which they wear are those of the adult birds. As with young cuckoos, the feather sheaths do not break open until the feathers have nearly matured, and, for a time, their bodies are incased in the same curious coats of mail.

With most species of kingfishers the males and females are very similar or the females may even be a trifle brighter than the males. This is very uncommon among birds, for if a

species is brilliantly colored the bright feathers are usually found only on the male and the females are much duller. With birds that build open nests this is necessary, for bright colors would call attention to the female while incubating and result in her destruction. With birds that have always nested in cavities, so that the female is entirely out of sight while on the eggs, there is no such need for protective coloration and the females are often brilliant.



FEMALE KINGFISHER, WITH SMALL FISH FOR ITS YOUNG



YOUNG KINGFISHERS IN THEIR PARTIALLY GROWN FEATHERS

Among our American birds we find this to be the case with the woodpeckers as well as the kingfishers. Among tropical and Old World species there are many, such as the trogons, toucans, hornbills, bee-eaters, rollers, etc., in which the females are as bright as the males. These birds have probably always nested in cavities and never developed the nest-building instinct.

All of the New World kingfishers, and there are but seven species, belong to the fish-catching group. They are either blue or bright green above, and white or russet below and vary in size from the little South American orange-and-green kingfisher, which measures scarcely five inches in length, to the large ringed kingfisher that occurs as far north as southern Texas, and measures sixteen or seventeen inches.

The only species found in North America, north of Texas, is called the "belted kingfisher". It is about thirteen inches in length, but, because of the shortness of its tail and the heaviness of its body, it appears larger than the measurement would suggest. It is found in summer along streams, or about lakes and ponds, from northern Alaska to the Gulf, and in winter commonly from Ohio to northern South America. Occasionally it winters as far north as New York or New England, where it can find open water.

The kingfisher is bluish gray above and white below, the white of the underparts extending around the neck in a broad ring. Across the breast and down the sides is a bluish gray band which, in the female, is tinged with rusty. The female, moreover, has a secondary band of rufous below the gray band. The head of both the male and the female has a curious double or interrupted crest which is always erected when the bird is alarmed or nervous.

The kingfisher has two methods of fishing, either waiting on a branch or projecting rock over the water for its prey to swim beneath, or flying rather high over the water until it locates a fish swimming near the surface, when it hovers for a moment on rapidly beating wings. In either case the plunge is made head foremost, with closed wings, and the fish is speared with the sharp, javelin-like bill.

The bird itself is carried entirely beneath the surface of the water by the force of the fall, but, rising immediately, returns to its former perch, juggles the fish about until it gets the head directed downward and swallows it entire. The size of the fish which can be swallowed is quite surprising. The indigestible bones and scales are later ejected from the mouth, much as in the owls, in the form of pellets.

The kingfisher always nests in a hole drilled into the perpendicular bank of a creek or sometimes far from water in a gravel pit or railroad cut. The hole is usually within a few feet of the top of the bank and is directed inward and upward for from four to ten feet and enlarged at the end. No nest is built, but the bones of fish which it has eaten often line the cavity. In drilling the kingfisher uses its bill and pushes the soil out with its feet.

Kingfishers are wary birds and, no matter how carefully approached, will permit one to reach only a safe distance before flying off, with a loud rattling cry, to their next perch. They usually have a number of favorite perches along a stream but their hunting range is rather limited and when frightened upstream from one perch to another, they soon make a wide detour back to their starting point. Their flight is strong and direct, and when coming head-on is so very duck-like that hunters have been known to fire at them, thinking until too late that they were ducks.

About trout streams or artificial ponds where valuable fish are being raised, the kingfisher is sometimes quite destructive to the young fish. It is therefore not protected by law. In most places, however, the fish taken are minnows or suckers or others of little or no commercial value. The kingfisher is far too picturesque a bird to warrant wholesale destruction. Even the most careless gunners and the most inveterate fishermen seem to have a wholesome, friendly interest in this little pirate of the stream, so that relatively few are shot for the mere sake of killing. It is probably for this reason, in addition to its wariness, that it is still a common bird wherever there are suitable conditions for food and nesting.

THE ORIGIN OF THOUGHT

Man's Growth as a Thinker through His Superior
Brain-Facility for the Association of Ideas

THE PUTTING OF TWO AND TWO TOGETHER

WE have found, on comparing the cortex of the human brain with that of the nearest mammal, that its very much greater size depends, in only relatively small degree, upon the enlargement of those areas to which we can assign definite functions. The greater part of the enlargement is due to the separation of these areas by large portions of the cortex to which we can assign no special function, but which must surely be of high importance, since they, above all, distinguish the human cortex from its inferiors. On microscopic examination of these areas and their connections we find very definite evidence. All nerve fibers which proceed from them do not run to the spinal cord, on their way to some relation with the body, nor do they go to the cranial nerves, which control the movements of the eyeballs and so forth. Some go to other parts of the cortex itself, and there they end.

As for the nerves which come to these areas and end around their cells, they are found to come from other brain areas. In a word, these are clearly association areas. They connect all parts of the brain with all other parts. They have no other function, and they are called the "silent" areas, because they yield no reply on stimulation, but their function is, in some ways, the highest and newest of all. This does not mean, of course, that no animal has association areas, or is incapable of the process of putting "two and two together", which we are about to study. But the most characteristic fact of the human brain, in respect to function, is just its unique development of the faculty of

putting two and two together, which we shall see to be practically equivalent to what we call thinking. We thus have what appears to be a thoroughly satisfactory correspondence between a special characteristic of structure and a special characteristic of function.

The reader will be tempted to assume that these do really account for each other, and that the process of thinking does just consist of the sending of impulses through the systems of association fibers from one part of the cortex to another. No doubt that is involved, but close examination of this idea will show that it is much too simple. When we look at the processes of, say, mathematical reasoning, we really cannot get them to correspond to our picture of the brain, with its association areas and systems of fibers. Still, their unique development in the human brain remains, and we may be sure that it somehow plays an important part in thinking.

A better and deeper interpretation of these association areas is now available. Examination of them and their fibers at early ages shows that they are very late in development—which corresponds, of course, to the fact that they occur last in the history of the evolution of the brain. No doubt their function must be very high, and specially human. We find, further, that there is an element of modifiability, inconstancy, almost "fluidity", in the structural arrangement of these parts, contrasting with the rigid, constant structure of lower and older parts of the brain, which are laid down in a fixed fashion, practically identical in all individuals, long before birth. Now, there can be no

doubt as to the great human characteristic which corresponds to these facts. It is the power to learn. This is sometimes called educability, sometimes docility, but it is, at any rate, that great characteristic of man in virtue of which he learns by experience, and so adapts his behavior, to a degree which is without parallel in the animal world, and which essentially accounts for his dominance in the scale of nature.

Lankester introduced this term "educability", in 1899, and, though it is clumsy, it is expressive. In his Romanes Lecture, a few years later, he returned to the subject, asking to what the increased bulk of the brain in man, and to a much less degree in the latest forms of various other mammals, was due. The smaller, older brain is perfectly efficient; its possessors "carry on a complex and effective life of relation with their surroundings".

The true significance of the increased bulk of the human brain

"It appears that the increased bulk of cerebral substance means increased 'educability' — an increased power of storing up individual experience — which tends to take the place of the inherited mechanism with which it is often in antagonism. The power of profiting by individual experience — in fact, educability — must in conditions of close competition be, when other conditions are equal, an immense advantage to its possessor. . . . It is obvious that the opportunity for those individuals with the most 'educable' brains to defeat their competitors would arise. No marked improvement in the instrument being possible, the reward, the triumph, the survival, would fall to those who possessed most skill in the use of the instrument. And in successive generations the bigger and more educable brains would survive and mate, and thus bigger and bigger brains be produced. . . . The result is that the creature called Man emerged with an educable brain of some five or six times the bulk (in proportion to his size and weight) of that of any other surviving brain."

Such is Lankester's account of the human brain.

The newer association areas of the brain the parts that make men educable

And all the recent psychologists are in agreement with him, and teach us to regard the association areas as essentially the organs by which man learns. Here, for example, is a recent statement: "There is present at birth a vast number of nervous elements which become only gradually organized, modifying and combining the congenital systems in extremely complex systems which constitute acquired dispositions to modes of action peculiar to the individual. The number of the elements of this nature is so great that the areas of the cortex of the cerebrum in which they predominate, those which surround the various sensory areas and are known as the association areas, are considerably more extensive than the sensory areas, which in the higher animals make up the greater part of the cortex. The greater relative size of the brain of man is chiefly due to the development of these parts. The very great capacity for learning by experience, rendered possible by this vast mass of nervous elements not congenitally organized, distinguishes the mind of man, and raises it immeasurably above that of the highest animals."

Of course, very special attention has been directed by anatomists and students of development to these areas and systems upon which the supremacy of the human brain, and therefore of man, depends. Some of them, for instance, which are closely associated with voluntary movement, and its "educability", can be shown to be much smaller in apes than in men, still smaller in the dog, scarcely visible in the rabbit, and entirely absent in the lower vertebrates. The reader will remember Bergson's demonstration of the *unlimited* character of the human brain, which can make new instruments for life, and is not confined to those which the body of man itself comprises. Here we see the anatomical structure which corresponds to this power of the human brain.

It has already been mentioned that these parts of the brain are late in reaching their full development.

The association areas of the brain not fully laid down till adolescence

This question has been specially studied by a famous German embryologist, Paul Emil Flechsig. Most nerve fibers run in a white or medullary sheath of what is perhaps an insulating material, which keeps the current in its place. However that may be, we are sure that nerve fibers which are destined to have this sheath, or "medulla", do not perform their functions until its appearance. In the brain of an infant very many fibers are already properly medullated, and can do their work, or of course the infant could not live. But many are not. Study along these lines helps us to distinguish various tracts in the brain, and to define their order of development; indeed, we owe most of our knowledge of the association systems to Flechsig and this method. He has shown us that, at birth, the association system is very imperfectly developed, and that some parts are actually not laid down in working order until after adolescence. They are thus last to come, alike in the history of the race and of the individual. Their non-development is probably responsible in large degree for the non-educability of the feeble-minded and other defective types of brain. Their owners can only learn to a very limited extent, and remain children, or lower, all their days, so far as mental capacity is concerned.

So much for the anatomists. Let us now look more closely at the psychical side of this question. The anatomists can help us no further; what we now require is introspection and observation of the mental processes of ourselves and others.

The discovery by Hobbes of the law of association of ideas

Here our study goes back, far before modern knowledge of the brain, to the celebrated English thinker, Hobbes, who first clearly discovered and laid down the law of the "association of ideas", as it is called. We shall see, on consideration, that docility or "educability", the power to learn by experience, does, in fact, mean the power of forming associations in mind

and brain, and retaining them. Thinking, from its lowest to its highest forms, is relating — "putting two and two together", forming associations which guide us in the future. The theory of the association of ideas thus constitutes one of the foundations of psychology. First stated by Hobbes, then restated by Locke, and again discussed by John Stuart Mill and many other English psychologists, the association of ideas has given its name to what is often called the "Associationist", or English, school of psychology.

In its simpler forms the association of ideas is obvious, though, indeed, the word "ideas" is rather too limited to use. We associate not merely ideas but all manner of sensory experiences, simple and complex. Thanks to memory, these associations in large degree persist, so that our conduct is modified thereafter.

Association of ideas as seen in the conduct of intelligent animals

We have all observed and commented upon the association of ideas, so called, in intelligent animals. A dog that has been ill-treated by a man in uniform when it was a puppy, hates and fears all men in uniform ever after. This is the essence of thinking, associating, relating, learning by experience; and the greatest successes of the human mind depend upon one and the same process. Indeed, if you know what are a man's associations with a random assortment of things, a star, a name, a book, a tune, you begin to know the very man. This is how we are able to judge of one another by our talk, for our talk betrays our associations with whatever topic turns up; and according as one and the same topic suggests different comments and "trains of thought" to different men, so largely can you know those men, their history, their interests and purposes.

We are very liable to think of the association of ideas in purely mechanical terms, as is almost inevitable when we observe how prone we are to form associations between things which merely happen to be seen at the same time, though there is no other relation between them. But this purely mechanical view of the association

of ideas is quite inadequate. Like the whole of our mental processes, which the nineteenth century used to interpret as a kind of "motion picture" succession wherein the mind merely played the part of a passive plate, the association of ideas, from its lowest to its highest, includes a volitional element, due to the vital interests, concerns, intentions, desires, of the individual in question. Otherwise, we should all derive similar associations from similar experiences, and should retain them similarly; nothing could be further from the truth.

The influence of our own wills and interests on association of ideas

The so-called laws of association are no doubt mechanically true in part, but they do not express the whole truth. What you see, and what you associate, mightily depend on what you are looking for. It is not true that the "laws of association" drive us about from pillar to post as if we counted for nothing. On the contrary, we each go our own way from similar beginnings, partly because our minds are already stored with different associations, but far more because each of us has his own interests, and thinks accordingly. We wish for something for ourselves, or we hold a belief, in some religion, in money, in evolution, in some scientific theory, in socialism, or what not; and this belief determines the character of our associations and our thinking in general.

How will this affect *me*, or someone I love, or my church, or my belief, or my enemy, or the unborn? These are the questions always asked, respectively, by various kinds of people, according to what they are; and though they all form associations of ideas on similar lines, they use those lines, each in his peculiar way, for his own peculiar ends.

Another criticism to be passed on the purely mechanical theory of association is that it takes too little account of the motive force which drives the chain of associations. Two men may have two very similar brains, may have had very similar experiences, but when you place them in similar circumstances, and expect them both to reach similar conclusions, you are disap-

pointed. The fact is that one of them reaches no conclusions. The chain does not run. If, for some special reason — say, money, or ambition, or self-protection — he were really to be started "thinking on those lines", as we say, he would reach the expected conclusion, but, as a matter of fact, the process stops for lack of motive. The truth is that, as Locke said, the greater part of mankind think very little and very seldom. If they are hungry and notice the smell of food, they think of dinner; and throughout the day they achieve various similar associations but little more. Beyond a certain humble stage, in which many animals may share, as in the case of dinner, we really require some special interest or motive to keep our association sequences going.

The notion that it is purely mechanical and automatic, so that you put in a certain idea or sensation, and then the "wheels begin to go round", is mythical. Every propagandist knows better. The trouble is to get people to think. The machinery is there, and the appropriate start can be made, but nothing happens, because the living will, the purpose, the *élan vital* of the individual, has not been engaged; and after a stage or two the process simply stops for lack of motive. Undoubtedly there is a mechanical element in thinking, which we cannot unjustly represent in terms of the association of ideas, and in pictures of association fibers connecting eye and ear, and so forth, but we go very far wrong if we suppose that this machine will work without power being put into it. That power is the vital intention of the individual, and it is a *sine qua non*. It may be adventitiously aroused, as when a boy studies a subject for a prize, or a politician advocates and "gets up" a subject of another kind for a prize of another kind, and afterwards they never think of the thing again. Or it may be *organic*, whether sane or mad, unselfish or selfish, trivial or momentous; and then the mind of the individual will work along these lines always, not as the ivory ball rebounds from successive cushions of a billiard-table, but as a man goes from point to point because he means to get somewhere.

This is a very profound question, because it involves our understanding of the different types of minds and of men.

We recognize one man as a "great thinker", and another as nobody in particular. Perhaps we assume that the first man was necessarily more highly endowed with association fibers, and so forth, than the second. He had a different kind of brain, which enabled him to do these feats. In part, of course, this may be true, but it is certainly not the whole truth.

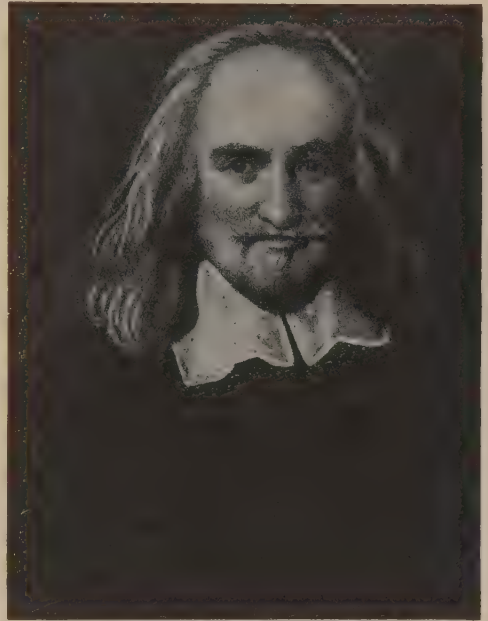
The difference that makes a man a great thinker not usually one of brain structure

Examine the work of one of these great thinkers, and you may find that the taking of any given step, the forming of any given association, was not in itself an exceptional feat. Any of us could have done it — if we had "had the mind", in one sense of that phrase. The second of our two men may have been much more richly endowed than the first, he may have had more opportunities, and the "laws of association" should have done the rest. But, in fact, nothing happened. There was no motive; he did not care; other things attracted him. The man we call the great thinker really had no better a machine, *but he chose to use it*. This view, which is in harmony with general experience, consorts with the view of association which we have just laid down. It gives us the truth that character, the vital drive of a man, the direction of himself, is the most important fact about him. Of course, the machinery is important also, but we must no longer try to interpret the man and his processes solely in terms of his machinery.

Motive power, not body, in men as in automobiles, what really counts

In a letter to his cousin Sir Francis Galton, Charles Darwin wrote, on this very question: "I have always maintained that, excepting fools, men did not differ much in intellect, only in zeal and hard work; and I still think this is an *eminently* important difference." We are here discussing the physical and psychical basis of what we call intelligence or the intellect, and Darwin's verdict doubtless stands, in large

measure. Exceptions there are, both in the case of certain individuals and in the case of special kinds of intellect, like that associated with mathematics. But the word "zeal", which Darwin uses, counts for far more than difference in intellect, when we compare the greater number of men with one another. Unfortunately, while it is easy to lay down semi-mechanical laws of association, and even to show how the structure of the brain seems to correspond to them, when we come to "zeal", "interest", the motive power which is present in one man, so that he uses his machine, but absent in another, so that he



THOMAS HOBBS

does not, we pass beyond the limits of knowledge and of material evidence altogether.

Meanwhile the laws and conditions of association, for what they are worth, must certainly be studied. If we consider our own minds we recognize at once that they have a sort of acquired structure which depends upon their experience, largely determined by their interests. In virtue of it we think of things together, or in sequence; we have once thought of them, or have perceived them, in some relation, and we can think of them again in the same relation.

An interesting memory test that incidentally illustrates association of idea

Links of some kind — the nature of which we can imagine as we please — have been formed in our minds, and so the "chain of ideas", as we often call it, can be reproduced at will. Anyone can illustrate the association of ideas for himself, and can also discover a very important fact about what we call memory, by simply writing down a string of nouns, fifty or more, in a column, and then reciting them without a flaw, as he certainly could not do if their sequence did not depend upon such links already existing in his mind.

Thus, noun suggests school, school a particular teacher, his name the name of the place he occupied in the field of science, science suggests biology, biology Pasteur, Pasteur France, France the Battle of the Marne, Marne America, and so on as long as you please. But no two people will compose the same sequence, though all start with the idea "noun"; and, on the whole, the character of the sequences to which we incline will depend upon something deeper than the so-called laws of association.

Elaboration of this game the basis of scheme for aiding the memory

It is upon greatly elaborated systems of association of this character that the greatly advertised schemes for assisting the memory are in many cases constructed.

The last great "associationist", the late Professor Bain, of Aberdeen, whose books, such as "The Senses and the Intellect", go back to the 'fifties of the nineteenth century, always maintained that intellectual or philosophic genius depended upon the number, variety, range and fitness of the associations of ideas. But that in turn must largely depend, as we have tried to insist, upon deeper factors of the mind.

The active part played by the mind in forming associations

Dr. McDougall not long ago wrote confirming the newer view of association which the associationists, from Hobbes to Bain, ignored.

Here is his comment on this: "Thus if I have on one occasion seen a cat seated on the back of a pony, I shall be apt to think of that cat whenever I again think of that pony. The static method describes the fact by saying that the idea of the pony is associated with the idea of the cat, and that the one idea, therefore, reproduces or tends to reproduce the other. . . . The most important point to note is that the mind does not play a passive part in the formation of associations. Objects become associated for the mind, not merely because they are presented to the senses simultaneously or in immediate succession, but when and because the mind perceives or otherwise thinks of them as related with one another; and it does this only in so far as it is interested in them as so related, that is to say, in so far as they stir up some conative [willing] tendency. To go back to the instance of the pony and the cat: if, at the moment my glance fell on the two animals, the cat had been seated on the ground at some little distance from the pony, I should have noticed both animals only in the most fleeting fashion, if at all, and I should not have associated them together. But this spatial relation implied a friendliness between them which is unusual, and appeals to my interest in the behavior of animals; hence, out of all the details of the scene presented to my vision, my mind seizes upon these two animals.

Contiguity and similarity as the two modes of mechanical association

"It may be remarked in passing that this example illustrates the impossibility of describing even so simple a process of association as this in terms of sensation and imagery. The mere spatial relation of the two visual forms is of no interest. It is only because they mean for me far more than is actually presented to the eye that the situation appeals to an interest, and draws my attention."

Given that we realize and accept this truer and deeper view of the association of ideas, there is no harm in our noting the quasi-mechanical laws upon which past psychologists have spent so much study.

It used to be said that association of ideas acts in four ways — by contiguity, simultaneity, similarity and contrast. This fourfold classification may certainly be simplified. Contiguity in space, as, for instance, when an old tune recalls the surroundings in which it was first heard, and simultaneity or contiguity in time, as when the memory of one occurrence arouses the memory of another that happened on the same day, or during the same holiday — these two are both reducible to the single principle of contiguity, either in space or time. Likewise, similarity and contrast, the one being merely the negation of the other, are reducible to one principle; so that the modes of association are really reduced to two — contiguity and similarity.

The rich variety of the mind in forming associations

But these laws or modes of association may work upon all manner of levels. For instance, in conversation a man uses a word which stirs associations in both of his hearers; but whereas in one the association is rational and subtle, beyond psychology to define in mechanical terms, in the other the association is purely sensory and auditory, and leads to the making of a poor pun. The word has suggested another word of similar sound, but no association in meaning. Similarly, in popular catch-words, "king and country", "fifty-four-forty or fight", there is an associative element which is purely sensory, and depends upon a similarity of consonantal sound. The virtue of alliteration or "head-rhyme" is thus explained.

The higher levels of poetry no less susceptible to the laws of association

But the same is true in poetry, and end-rhyme; and every critic soon learns to detect and appraise the level of association on which the poet's mind was moving. Love, dove; pearl, girl; moon, June; star, afar; ocean, motion — these all require careful observation on the part of the critic, in order to decide how far the merely sensory element in association, as against the rational and imaginative elements, has determined the poet's pen.

Everyone who is familiar with the poetry of, say, Longfellow and Walt Whitman knows the difference. The two poets each have their definite associative tendencies, certain words and ideas occur, and we may be fairly sure to what they will lead in an ensuing line, but the plane of association is very different in the two cases.

The way in which a clever man can deliberately play with his "faculty" of association, on all sorts of planes at once, is illustrated in much humorous verse, like that of Walt Mason or Lewis Carroll. The latter could at will associate ideas rationally, as in his mathematical treatises, or with a mixture of reason and unreason and mere attention to similarity in sound, as in his delightful "Alice in Wonderland" and "Through the Looking Glass".

The tendency of associations to become fixed and sacrosanct

The element of association in language is well illustrated in onomatopœic words — in which, that is, the name makes the sound named. The Greeks, who coined the term, were great users of onomatopœia, as familiar quotations will recall. Such words are hush, hum, buzz, whirr, whisper, tinkle, rustle, cuckoo, and a host besides, in all languages.

Here there is a perfectly rational association. In other instances, the association between the word and the thing is purely arbitrary. But it is constant, and after a time it comes to wear the aspect of being rational and inevitable, the mind supporting the association between sound and sense to be inherent in the nature of things, as in the case of the old ball player who was asked why a left-handed pitcher is called a "south-paw", and replied: "Why, what else could you call him?"

Early and long-repeated associations tend to become sacrosanct, natural, part of the eternal order of things in this fashion, and when they are broken we are shocked or bewildered beyond measure — as, for instance, at proposals for rational spelling, or at the suggestion to modify a religious ceremonial, which wears for many the aspect of an attack upon religion.

The high importance of the relation between association and memory

Thus we carefully observe that, though all thinking is relationing, or the association of ideas, and though the "laws of association" appear to be general and simple enough, yet there are all levels upon which they work, from that of the old lady who thanked the preacher for the reiteration in his sermon of "that blessed word Mesopotamia", up to the mind of Newton, which leaped from a falling apple to a falling moon.

The association of ideas cannot be left without reference to its high importance in relation to memory. Here we speak, of course, not of sheer memory, which is retention pure and simple, but of the reproduction, the accessibility, of what is retained. It is argued by many psychologists that the purely retention-factor in memory is unmodifiable in each individual, by any means. It appears gradually to decline with advancing years, and is never keener than in the "teens". But far more important is the power to use and to connect what one knows. This depends upon association. The great thing is to have as many hooks as possible with which one can fish up a fact or an idea, or any other memory, from the depths of the subconscious mind. This is achieved by thinking over what one learns, for thinking is associating, relating, and means that new connections are being formed with the memory in question, in virtue of which it will become proportionately more accessible and available in the future.

Associations that resound most curiously through the senses and link them up

A word may be added regarding what is called the "association of sensations". This is a psychological abnormality, though not to be called morbid. Its subject hears trombones, perhaps, and has an associated sensation of crimson. Certain vowel sounds may have definite color-sensations associated with them. Cases are recorded where colors evoke sensations of hearing, where hallucinations of smell and of taste are aroused by color and sound, and *vice versâ*, but by far the commonest are those of visual sensation aroused by sound.

It is probable that such musicians as Wagner, and doubtless many poets — "I see the crimson blaring of their shawms" — have been the subjects of association of sensations, but the most numerous instances are recorded among the insane. The cases are striking, because they correspond so well to Hume's theory of the physical mechanism of association — that when any given nerve cell is excited an impulse passes along the nerve fibers which connect that nerve cell with some other, and causes it to yield up its idea, as a bell yields up its note when it is struck. Thus the visual cells are aroused by impulses from auditory cells in action, and yield their specific psychical function, which is vision, according to the law of Müller. Of course, such a theory is hopelessly inadequate when we come to deal with the association of real ideas, but it seems to explain these cases of the association of sensations fairly well.



CHEMISTS AND PHYSICISTS III

SIR HUMPHRY DAVY—WHO REVOLUTIONIZED THE CHEMISTRY OF HIS DAY

SIR JAMES DEWAR—WHO LIQUEFIED HYDROGEN AND MADE AIR SOLID

EMIL HEINRICH DU BOIS-REYMOND—NOTED PHYSIOLOGIST OF THE NINETEENTH CENTURY

GABRIELLO FALLOPIO—WHO DESCRIBED THE MINUTE ANATOMY OF THE EAR

MICHAEL FARADAY—THE FOUNDER OF ELECTRICAL SCIENCE

EMIL FISCHER—GERMAN CONSTRUCTIVE CHEMIST

JOSEPH FRAUNHOFER—“*APPROXIMAVIT SIDERA*”

AUGUSTIN JEAN FRESNEL—BENEFACITOR OF “SHIPS THAT PASS IN THE NIGHT”

CHARLES FRIEDEL—AND THE SORBONNE CHEMICAL LABORATORIES

SIR HUMPHRY DAVY

Who Revolutionized the Chemistry of His Day

HUMPHRY DAVY was born at Penzance, Cornwall, on December 17, 1778, the son of a wood-carver.

At school he was a somewhat wayward genius, inapt to learn set lessons, but the hero of his fellows, whom he entertained with stories and poems without end. His father died, when Davy was only sixteen and his godfather John Tonkin, a prosperous surgeon of Penzance, apprenticed him to an apothecary, intending that he should eventually become a doctor. It was in the garret over the shop that Davy began the experiments which were to immortalize him. With the pots and pans of the kitchen, the vials and drugs of the shop, he fashioned his first apparatus; and an old air-pump, given him by the doctor of a wrecked French vessel, served to unbar the portals of pneumatic chemistry.

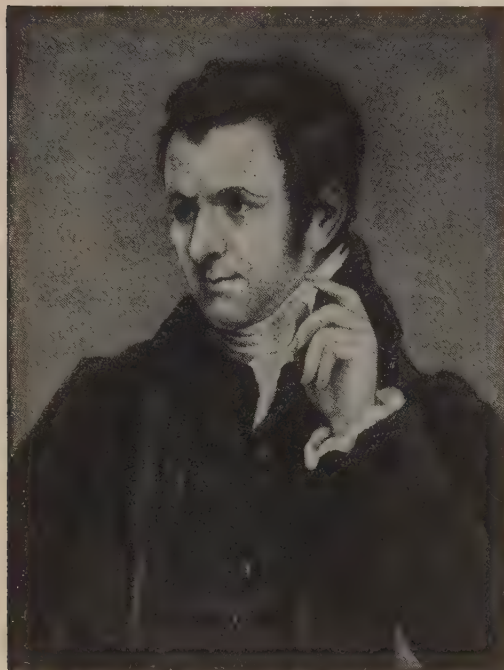
Davy had the good fortune to make friends of persons of influence at Penzance, visitors and residents; and when Dr. Thomas Beddoes established at Clifton his pneumatic institute for the cure of diseases by the inhalation of gases, Davy, aged twenty, went, much against Tonkin's will, as his assistant. Here he had an opportunity of studying in the well-equipped library of Beddoes. Experimenting with the then little known nitrous oxide, or “laughing gas”, he wrote, in 1800, of the power of the gas to ease pain, and predicted its use in the performance of surgical operations.

Davy had already published his first series of observations on “Researches, Chemical and Philosophical”, and this highly suggestive and original work led to his appointment as assistant lecturer at the chemical laboratory of the Royal Institution.

He gained immediate success. His lectures and novel experiments attracted audiences such as no scientific lecturer had ever previously addressed, and he was quickly promoted to the foremost position at the institution. Having at his disposal one of the best electric batteries then existing, he began the famous investigations which resulted in the epochal discovery that the alkalis and earths are compound substances formed by oxygen united with metallic bases. Proceeding from the investigations of Galvani, Volta and others, he sought to prove that if the poles of a sufficiently powerful battery were brought to bear upon any chemical compound, the components might be separated. The result was his discovery of the elementary metals, potassium, sodium, magnesium, calcium, strontium and barium.

Another discovery of equal moment was that by which he proved that chlorine is an element, and muriatic (hydrochloric) acid a compound of chlorine and hydrogen. Davy's announcements caused the overthrow of a vast weight of scientific opinion; and the attitude of many of his contemporaries was expressed by a noted Scottish professor, who, addressing his students on the subject, alluded to the now famous discoverer as “one Davy, of London—a verri troublesome person in chemistry”.

Davy was now at the zenith of his fame. Irish agriculturists raised a public subscription to induce him to lecture on agriculture in Dublin; and his discourses on the science of agriculture marked a new departure in scientific farming. He was knighted in 1812; married a gifted widow of fortune; resigned his chair at the Royal Institution to become honorary professor of chemistry; "discovered" Faraday, and traveled with him on scientific pilgrimages in Europe, honored by passports from Napoleon when England and France were at war; invented his safety lamp for



SIR HUMPHRY DAVY

mines, "one of the most valuable presents ever made by science to humanity"; and became president of the Royal Society. He continued his researches in chemistry and electromagnetism until he could no longer work, and died at Geneva on May 29, 1829.

Coleridge, who was among his illustrious admirers, overpraised Davy's poetry, but correctly estimated the value of his work to the world when he said, "He has shown that one common law is applicable to the mind and to the body, and has enabled us to give a full and perfect amen to the great axiom of Bacon, that knowledge is power."

SIR JAMES DEWAR

Who Liquefied Hydrogen and Made Air Solid

SIR JAMES DEWAR was born at Kincardine-on-Forth, Scotland, on September 20, 1842. Educated at Edinburgh University, he was at twenty-one appointed assistant to Lord Playfair, then professor of chemistry there, from whom he received the principal part of his chemical training. In 1868 he spent a few months at Ghent, under the celebrated chemist Kekulé. Here he continued some researches on coal-tar that he had begun at Edinburgh, and from them was developed the Dewar-Körner theory of the pyridine ring, that has helped chemists to produce artificially some of the most complex of organic substances. Sir James Dewar has done good work in many branches of chemistry and physics. One of his important practical discoveries was that of smokeless gunpowder, made in conjunction with Sir Frederick Abel, who also aided him in developing other high explosives used by the British government for military purposes.

The field of work in which Dewar has won most fame is that of researches into very low temperatures. On the occasion of the celebration of the centenary of Faraday's birth, in 1891, he showed in a lecture at the Royal Institution that oxygen, which is but faintly magnetic at ordinary temperatures, becomes highly susceptible to magnetism when subjected to a great degree of cold. He was the first scientist to succeed in preparing large quantities of liquid oxygen, and, by means of the Dewar vessel or bulb, he was able to store the liquid for long periods and so use it as a cooling agent. His inventive genius was displayed in using charcoal to make a vacuum in the double wall of vessels of light metals, such as copper, nickel and brass. As the vacuum flask was a non-conductor of heat, its employment led up to his crowning achievement of obtaining hydrogen in the liquid state; but, owing to a characteristic of British manufacturers, it was left to another nation to exploit in a commercial way the thermos bottle.

Sir James Dewar was only interested in the scientific use of his flask. It enabled him to tackle the problem of liquefying hydrogen, which is, next to helium, the most elusive of all gases. In a series of difficult and dangerous experiments the temperature was brought down to -258° , at which point the gas was transformed into a solid resembling frozen foam. This was

regular diminishing volume of gases, and the gradual falling off in the resistance offered by metals to the passage through them of electricity.

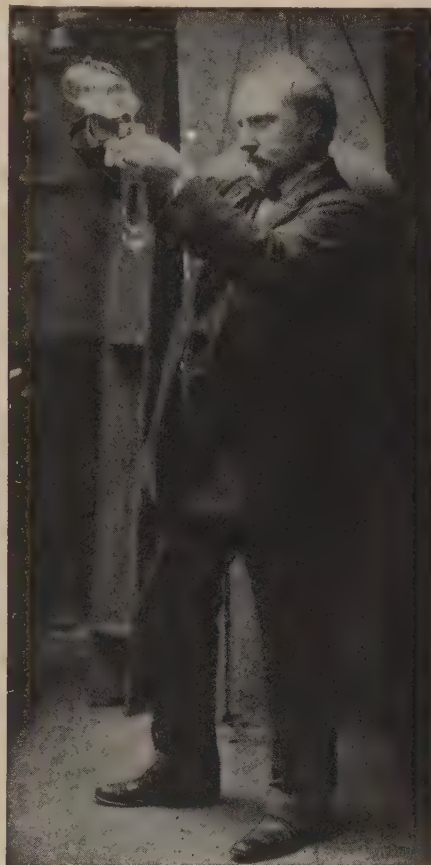
After his success with hydrogen, Sir James in 1906 tackled the last problem in the liquefaction of gases, and took up the study of helium. This gas is given off by the King's Well at Bath, and here the



WHY A THERMOS KEEPS THINGS HOT

The thermos bottle is made of two very thin glass flasks one within the other, the inner side of the outer and the outer side of the inner being silvered. The air between these silvered surfaces is exhausted, leaving a vacuum, and all these conditions prevent the contents of the bottle losing their heat or cold.

again cooled by further exhaustion to -260° , the lowest steady temperature that had ever been reached on earth. At this low temperature air and every other gas but one, helium, that is at present known to chemists becomes a solid. As Dewar remarked, "As we approach the zero point of absolute temperature, we seem to be nearing what I can only call the death of matter." The existence of this strange condition of things is indicated by the



SIR JAMES DEWAR EXPERIMENTING

The double flask invented by Sir James Dewar and known as the Dewar vessel or bulb is a double-walled, glass tube with the air removed from between the walls. It was the forerunner of the thermos bottle.

chemist arranged to accumulate it. But when two years' supply had been gathered in a glass vacuum vessel the vessel collapsed, and Sir James had to begin all his experiments over again. But though his researches were incomplete he was able to predict the probable properties of liquid helium. His prediction has been closely verified by Professor Onnes, the director of the physical laboratory at Leyden, who succeeded in producing liquid helium.

In 1875 he was appointed Jacksonian professor of natural experimental philosophy at Cambridge, and two years afterwards was made Fullerman professor of chemistry to the Royal Institution; he is also director of the Davy-Faraday Research Laboratory. In conjunction with Professor Moissan, he produced fluid fluorine, and was the first to study the important subject of the oxidation products of quinoline. He was knighted in 1904.

EMIL HEINRICH DU BOIS-REYMOND
A Noted Physiologist of the Nineteenth Century

EMIL DU BOIS-REYMOND, who was one of the most noted physiologists of the nineteenth century, professor of physiology in the University of Berlin and perpetual secretary of the Berlin Academy, was born in Berlin, November 7, 1818. He ranked with his contemporaries von Helmholtz and Virchow among Germany's greatest men of science, and in the special department of knowledge to which he devoted himself he laid the foundations in a new field, namely, electro-physiology. This activity was based on a critical study of the work that had been accomplished hitherto, and was extended by research and investigation of his own, in the course of which he developed methods and instruments for his contemporaries and successors. His earlier days were spent in Berlin, the city of his birth, where his father, who had begun life as a watchmaker in Neuchâtel, already had attained a position of importance. At least an inherited acquaintance with one of the trades of precision naturally stood the son in good stead, as much of his subsequent work was based upon the use and development of fine instruments. His mother was descended from Huguenots who had been forced out of France in the 17th century. Young Du Bois-Reymond received his early education at the College Français in Berlin, and later at the College of Neuchâtel. At the age of eighteen he entered the University of Berlin and was matriculated in the philosophical faculty, as his first interests were in theology, and particularly in the lectures of the ecclesiastical historian, August Neander.

In 1837 he came under the influence of Eilhardt Mitscherlich, the distinguished chemist, and other noted scientists, with the result that at about 1837 he devoted himself to exact science. He zealously studied the courses offered in mathematics, physics and chemistry, and then, turning to medical science, became a pupil of the distinguished anatomist and physiologist, Johannes Müller, who at that time was making Berlin famous as a seat of instruction in the sciences directly related to medical education. Interested in this work he became Müller's assistant in physiology, and in 1841 was asked to repeat the observations made recently by Carlo Matteucci on animal electric phenomena. The work of Matteucci and Nobili had suggested vast possibilities in this field, and Du Bois-Reymond began with a systematic historical study of the main facts as determined by earlier investigators. To this science, electro-physiology, he devoted himself assiduously in experimental work for forty years. His graduation thesis on "Electric Fishes" marked the beginning, and his great work, "Researches on Animal Electricity", the first volume of which was published in 1848, and the last in 1884, the climax of his investigations.

Du Bois-Reymond observed the electrical conditions developed through the contraction of muscles and found these and other phenomena could be studied by observing the deflection of the needle in the galvanometer. Constantly improving this instrument to secure greater sensitiveness, he was able to investigate a still wider range of phenomena. He devised a sensitive reflecting galvanometer, where the needle was so damped as to reduce its period of vibration, which was said to have suggested the reflecting galvanometer used for indicating signals on a submarine cable.

By 1858 he succeeded his old preceptor, Müller, as professor of physiology and director of the laboratory at the University of Berlin, Müller's chair of physiology and anatomy now being divided. In 1867 he became secretary of the Berlin Academy, to which he had been elected in 1848.

In 1877, under the direction of Du Bois-Reymond, there was built for the University of Berlin a great physiological laboratory. Here with a notable staff of professors and research scientists were combined material facilities and instrumental equipment to an unusual degree, and it attracted students from all over the world.

Du Bois-Reymond's life work was the investigation of the electrical phenomena of animals and plants, and he sought to establish the relation between them, especially the vital endowments of the structures in which they manifested themselves. He developed theories in electro-physiology, which though not universally accepted formed points of discussion for his contemporaries and future workers. He studied muscle currents, developing a theory of electro-motive molecules which, while not considered altogether satisfactory, nevertheless was actively discussed, and was attacked by such scientists as Ludimar Hermann. In his study of the electric phenomena of the muscles he developed a theory that when a muscle is excited each of its electro-motive elements sustains a diminution of its electro-motive force, the result of which was that in the muscle cylinder so excited the difference existing between a cut surface and its natural surface diminished. Other experiments had to do with the response of the nerves to variation in electro-motive force. In fact, Du Bois-Reymond covered broadly the field of electro-physiology as it then existed and laid the foundations for much future work.

As a notable physiologist of the nineteenth century he shared the highest honors of this science with Ludwig, who taught the investigation of the mechanism of circulation, and with von Helmholtz, who showed scientists how to determine the time relations of physiological processes of short duration. He founded a school of physiological thought of which Professor Bernstein of Halle became the most renowned exponent.

Not only was Du Bois-Reymond a successful teacher at the University of Berlin, but he enjoyed an international reputation as a popular lecturer in German, French

and English, with a wide influence in all of these countries. He was an imperial privy counselor, and a leading figure in the intellectual and political life of Germany. Being accepted at Court and sharing in the discussions of state, he was able to bring to bear on questions of the day, especially those concerning education and administration, the trained mind of a scientist and an unusual breadth of intellect. In all of this there was manifest the influence of the historic spirit of his early professor of theology, Neander, his own studies in philosophy, and the effects of his excursions into fields of science other than physiology and medicine during his student days. Du Bois-Reymond was one of those intellectual giants of Germany in the nineteenth century whose thoughts and activities were in no way restricted within the confines of their own professional chairs and the limits of their scientific laboratories. He died in Berlin, December 26, 1896.

GABRIELLO FALLOPIO

Who First Described the Minute Anatomy of the Ear

GABRIELLO FALLOPIO or Fallopius, an Italian anatomist, was born near Modena about 1523, and became a canon of that cathedral. He studied medicine at Ferrara, and after traveling through Europe, returned there to become a teacher of anatomy. When he was only twenty-five he was promoted from the University of Ferrara to a professorship at Pisa, and three years later at the instance of Cosmo the Great, Duke of Tuscany (the famous Medicean patron of learning), he accepted the chairs of anatomy, surgery and botany at Padua, succeeding Vesalius, who had been compelled to resign his office because, as the story runs, he had begun to dissect a body before life was extinct, and for this was prosecuted not only for murder but for impiety and narrowly escaped death. In addition to Fallopio's teaching he undertook the superintendence of the botanical garden connected with the university which had been newly established by the Venetian republic. He enjoyed considerable fame as a botanist, and a genus of plants, *Fallopia*, has been named after him.

At Padua, Fallopio carried on his study of the general anatomy of the bones; he was the first to describe with any accuracy the minute structure of the ear, especially the tympanum and its osseous ring, the two *fenestræ* and their communication with the vestibule and cochlea, while the canal along which the facial nerve passes after leaving the auditory is still known as the aqueduct of Fallopius. Better than heretofore he gave an account of the stylo-mastoid hole and canal, of the ethmoid bone and cells, the lachrymal passages, the muscles of the soft palate, and the *villi* and *valvulæ conniventes* of the small intestine.

He published numerous works in various departments of medicine of which the most important in myology is "*Observationes anatomicæ in libros quinque digestæ*" (1861), in which he criticized his teacher for many errors into which he had fallen and to which Vesalius replied in "*Observationum Fallopii examen*."

He also devoted attention to the organs of generation in both sexes, and the tubes passing from the ovary on either side to the uterus bear his name, although they were known to and accurately described both by Herophilus, the famous surgeon of the Alexandrine medical school, and Rufus of Ephesus three hundred years before our era. Fallopius, however, described their function.

He died at the age of thirty-nine in Padua on the 9th of October, 1562, and an invitation was forthwith dispatched to his master Vesalius, whom he had succeeded, to occupy again his old chair of anatomy. Vesalius consented and embarked for Europe, but was shipwrecked on the island of Zantë, where he died from exhaustion. Only one treatise by Fallopio appeared during his lifetime, namely the "*Observationes anatomicæ*." His collected works *Opera genuina omnia* were published at Venice in 1584. Fallopio was one of a fine series of anatomists, to which Italy gave birth, among the first eminent in Europe; indeed, the structure of the human body had been taught in the peninsula for more than a century before accurate knowledge of it had penetrated into other parts of Europe.

MICHAEL FARADAY

The Founder of Electrical Science

MICHAEL FARADAY was born in London on September 22, 1791. His father was a blacksmith, and Michael began his career, at twelve years of age, as an errand boy in the service of a bookseller. Here he remained until he was twenty-one, reading, experimenting in electricity with home-made apparatus, attending popular lectures by the lesser men of his time, cultivating valuable private friendships, and laying the foundations not only of his wonderful intellectual equipment but of that beautiful character which endeared him to so wide a circle.

When Faraday was in his twenty-first year, one of his master's customers found him poring over an article on electricity in an encyclopedia which he was binding. The visitor, ascertaining from his employer something of the industrious apprentice's character and habits, gave the lad tickets for the last four of a series of lectures which Davy was delivering at the Royal Institution. Faraday was present at the lectures, and has given us the story of the sequel. "I took notes, and afterwards wrote them out more fairly in a quarto volume. My desire to escape from trade, which I thought vicious and selfish, and to enter the service of science, which I imagined made its pursuers amiable and liberal, induced me at last to take the bold step of writing to Sir Humphry Davy, expressing my wishes and a hope, that, if an opportunity came in his way, he would favor my views. At the same time I sent the notes I had taken of his lectures." The effect was sensational.

Davy carefully considered his disciple's notes, realized that their writer had an exceptional grip of his subject, and promised to see him later. And it all happened in the manner of the fairy story. Faraday was getting into his humble bed one night when there was a thundering knock at the door, and, lo! the splendid carriage of Davy was discovered in the street. A servant in livery handed the apprentice a note, bidding him wait upon the great man next morning.

At the interview, Davy, after mentioning all the obstacles in the way of a scientific career, gladly took up the young man's cause, and in due season engaged him as assistant at twenty-five shillings a week. The transaction was one which did credit to Davy's discernment as well as to his generous nature, and, with all sincerity, he said in after life, when congratulated on his immense achievements, "My best discovery was — Michael Faraday."

Faraday soon came to assist his master in his lectures; shared the perils of the laboratory when Davy was conducting

have been a fortune in commercial pursuits, and at first declined a pension offered in contemptuous terms by Lord Melbourne, whose attitude was typical of the low esteem in which science and learning were held by the ignorant and intolerant governing classes of the age. When, however, Melbourne realized that he had a really great and noble man, as well as a mere scientist, to deal with, he apologized in the handsomest way, and made it possible for Faraday to accept a pension of £300 a year, to which in due course was added the tenancy of a house at Hampton Court.



MICHAEL FARADAY AT WORK IN HIS LABORATORY

his epoch-making discoveries; lectured in that lesser world in which he had himself gained his alphabet of science; then, when Davy went abroad, accompanied him, as valet and secretary. Upon returning to London, he plunged into new and unsounded deeps of science. Having already made a number of important discoveries in chemistry in conjunction with and for Davy, he succeeded the latter upon his retirement, in 1827, at the Royal Institution, with which, all told, he was connected for fifty-four years.

He refused its presidency and that of the Royal Society; he refused what might

Faraday's labors range over a great part of the domain of chemistry, electricity and magnetism. He kept a record of his experiments. The last is numbered 16,041.

From his work resulted the electric telegraph and telephone, and a myriad applications of electricity and electromagnetism which today are among the greatest driving forces of civilized communities. His experiments with chlorine crowned the work of Davy, and presented a gift of incalculable riches to the textile industries. He was among the pioneers in the creation of steel alloys, and from one of his first successes caused a

razor to be made which Tyndall used to the end of his days. His study of optics paved the way to great improvements in the manufacture of glass and in the illuminating of lighthouses. Photography is traceable to his investigation of the vaporization of mercury at an even temperature; his liquefaction of gases has been fruitful of many subsequent discoveries. Acoustics, the conservation of forces, the application of induced electricity to the firing of mines, lighthouses, telegraphy, etc.; the electrotonic composition of matter, the identity of various forms of electricity, whether from an eel or a battery; the equivalents in electrochemical decomposition, electrostatic induction, hydro-electricity, magnetic rotary polarization, and so on through an almost inexhaustible list—these are among the discoveries that make his name immortal, and his labors the foundation of electrical science.

Faraday was not only a great and successful discoverer in the untrodden ways of science; he carried a vast host of discerning disciples with him. He inspired with zeal and ardor a generation which worthily carried on the work that he had begun. He had the supreme gift of making the dry bones of science live. His lectures to the uninitiated were models of lucidity and charm. Without offending the intelligence of an audience, he remembered that they were not laboratory experts, and in language which all could understand, and high scientists not despise, he would tell the startling story of some new and revolutionary discovery with complete simplicity and directness.

This characteristic was one which greatly enhanced the value of his own work. He made the teachings of other men plain and attractive; he explained his own discoveries in terms which riveted the attention of all who heard him. His lectures, though designed to appeal to the intelligence of the unscientific, were always characterized by a simple dignity and beauty of language, often reaching real eloquence, so that a hundred records, from orators, scientists, artists, men of the world, attest the success of those wonderful séances at the Royal Institution.

In private life Faraday was gentle, charitable, trustful yet discerning, a very present help in trouble to those still struggling up the ladder of learning. He once thus summed up his career: "I am no discoverer, but simply one of a vast crowd of workers scattered over the earth, who in the providence of God are invested with some portion of the Divine afflatus, and appointed to show forth His mercy and loving-kindness in conferring fresh benefits on His people; the varied merits of such agents being evinced in the comparative zeal and self-sacrifice with which they carried out the mission entrusted to them." His biographer adds—"Faraday was one of that long line of scientific men, beginning with the savants of the East, who brought to the Redeemer the gold, frankincense and myrrh of their adoration." Faraday died at Hampton Court on August 25, 1867.

EMIL FISCHER
German Constructive Chemist

EMIL FISCHER, one of the greatest of German chemists, was born in Euskirchen, in Rhenish Prussia, on October 9, 1852, and died in 1919. He was educated at Bonn, and studied chemistry at Strassburg; then he acted as assistant to Baeyer at Munich for eight years. At twenty-three he made his first discovery of a new compound of hydrogen and nitrogen, known as "hydrazine", which proved to be of great practical importance. Later, he showed that Sir William H. Perkin's coal-tar dye, magenta, was derived from the base he discovered, and he also found the parent substance of indigo. In all this work he only trod in the well-beaten path of research of his master, Baeyer. But in 1881 he began more original work, and from this date his contributions to chemistry are unique in extent, character and completeness. The main significance of his work is its relation to the processes of living bodies—a subject of ever increasing interest. In an arid and sterile period in physiological chemistry, he turned the force of his genius to the making of substances intimately connected with the processes of life.

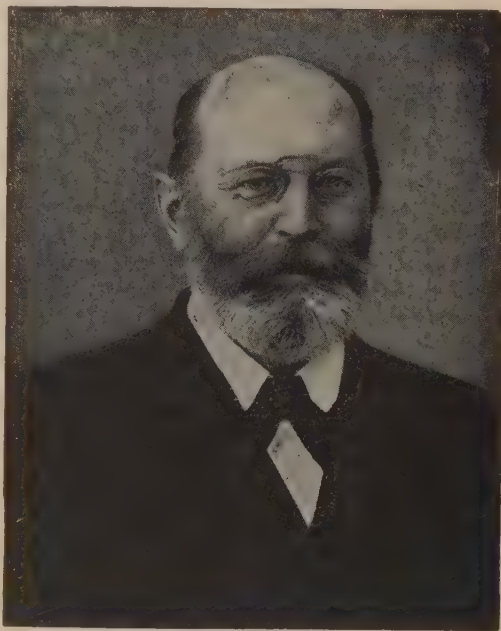
By 1883 Fischer had taken up the waste product of living bodies, urea, and had shown how it was built up and related to the stimulating principle in tea and coffee and cocoa. Then, by a remarkable skill in creation, he manufactured from uric acid the caffeine of tea and cocoa, and the theobromine in cocoa-beans and kola-nuts. He next attacked the sugars, and showed of what they were made, and in many cases made them in his laboratory.

On the death of Hofmann (1892), he was appointed professor of chemistry and director of the laboratory at the University of Berlin. Here he worked at the head of a brilliant group of assistants, drawn by his fame from all parts of the world. The most difficult and the most interesting of all branches of chemistry engaged his attention. This is the chemistry of the albumins, or proteins, which are colorless substances composing the solid constituents of animal tissues, and the secretions of animal and plant cells and other products of life. They play a most essential part in the world of living matter, and they are the most complex of substances.

In 1889 Fischer succeeded in breaking some of these albumin substances into simple amino acids, which are compounds of ammonia. The remarkable thing about Fischer's work was that he usually proved that his analysis of a substance was correct by taking the elements he found in it and building up an artificial product similar to or identical with the natural product. This he did in the case of the albumins or proteins. In 1910 he was able to show the German emperor a small amount of synthetic protein which could be used as food. It was the most complicated substance ever evolved by synthesis. The materials for it cost \$250, and if the labor expended on it had also been counted its price would have been still more extraordinary. It has not yet made its appearance on the dinner-table! But though today it is nothing but a chemical curiosity, some day it may be of the greatest value. For though it is simple in structure when compared with the white of an ordinary egg, it solves the mystery of the most complex forms of living matter.

Fischer himself considered that the synthesis of all the proteins is only a question of trouble and cost.

Owing to Fischer, chemistry has now become an important factor in the solutions of the great riddles of life — nourishment, growth, reproduction, heredity, age, and disease. He made out of ammonia the uric substances found in the muscles of the body and in the nuclei of living cells. He laid bare the structure of sugars and starches, which are among the most important foods of man, and he succeeded in creating these things by artificial means; and finally he attacked the proteins of



EMIL FISCHER

animal tissue. In 1912 he took up the study of the tannins, which were one of the mysteries of modern science. For sixty years chemists had been trying to find out their structure, but without success. Fischer discovered that by combining glucose with a certain kind of gallic chloride he could obtain a compound with all the properties of the tannins.

Fischer devoted much time to trying to solve the ultimate secret of the processes of living bodies. By a peculiar chemical power, living matter can quickly and easily break up gases of the air and foodstuffs into simpler substances. Things that take

a chemist a long time to perform are effected instantaneously in the living body. This is done by means of small amounts of curious chemicals produced by the tissues and known as "enzymes". At present they cannot be imitated in a chemist's laboratory, but Fischer found that they are related to more simple substances. If enzymes and similarly powerful small agents can be manufactured cheaply in chemical works, a new and mighty kind of force will be placed at the service of mankind.

JOSEPH FRAUNHOFER

"Approximavit Sidera"

ALL modern work in spectroscopy is based upon that of Fraunhofer, and his predecessors in the science are not numerous. Newton, in 1666, first observed the spectrum of the sun, when he allowed light coming from a small round opening in a shutter to pass through a glass prism. This spectrum was impure, and not until 1802 did Wollaston, repeating Newton's experiment, obtain a pure spectrum by replacing the round opening with a slit parallel to the edge of the prism. He observed dark lines crossing the spectrum, which limited, as he thought, the different spectral colors. Working independently of Wollaston, Fraunhofer, in 1814, rediscovered the lines in the solar spectrum, which now bear his name. He at first used a slit and prism; but later he discovered that the same phenomena could be obtained by means of gratings made up of wires or ruled on glass. Continuing his analysis, he applied the prism to the study of spectra of the sun, the stars, flames, etc. He was the first to measure the wave lengths of various solar lines, and to investigate the effect upon the spectra of periodic errors in the ruling of gratings, of the shape of the groove and the relative widths of opaque and open spaces.

Joseph von Fraunhofer was born in Straubing, March 6, 1787, and died in Munich, June 7, 1826. His father was a master glass-workman and at the age of twelve apprenticed the boy to a glass-polisher. In 1806 he became a working optician in the establishment of Reichen-

bach & Utzschneider in Benediktbeuern, and while there invented new methods, machines and measuring instruments to perfect the construction of achromatic lenses. In the course of his work he made the discovery of the lines in the solar spectrum which bear his name. With the aid of a prismatic-objective telescope, he studied the spectra of the moon, the planets and some of the stars, and upon presenting the results of his observations to the Royal Academy of Science of Bavaria, was elected a member. Fraunhofer became the proprietor of the optical concern which had moved to Munich in 1819, and became engaged in the manufacture of optical instruments. In 1821 he published his experiments on diffraction through one or more openings, and on the spectra obtained by gratings. In 1823 the paper was continued by further experiments with glass gratings and by measurements of the wave lengths of various solar-lines. In 1825 appeared his memoir on halos, mock-suns and allied phenomena. In the later years of his life he was appointed royal professor, and received numerous honors. He was buried in a plot of land given by the city of Munich for the purpose, and his tomb bears the simple inscription: "*Approximavit sidera*".

AUGUSTIN JEAN FRESNEL

Benefactor of "Ships that Pass in the Night"

AUGUSTIN JEAN FRESNEL was born May 10, 1788, at Broglie in Normandy. His father, an architect of considerable reputation, was engaged in the construction of one of the forts at Cherbourg, when the turmoil of the Revolution forced him to retire with his family to a small property near Caen. Here for thirteen years Fresnel lived, and was educated with his brothers by his father and mother. No one could ever have imagined that he would become one of the most distinguished scientists of his day, for at eight years of age he could hardly read. After three years in the *École centrale* of Caen, Fresnel entered the *École Polytechnique*, although it was feared that his health would not stand the strain of the full course. Signs of his latent talent

at last appeared, and his solution of a geometrical problem propounded by Legendre so attracted the attention of that famous mathematician that he complimented the young scholar in public. From the *École Polytechnique*, Fresnel passed to the *École des ponts et chaussées*, and upon leaving it was appointed engineer successively in the three departments of La Vendée, Drôme, and Île-et-Villaine. Whatever may have been his dreams of a first post — whether it was to join ocean and Mediterranean by a ship canal, scale the Alps with a highway that would successfully cross the eternal snows, or adorn Paris with a bridge whose marble should recall the chisel of David — the awakening must have been painful. Leveling small stretches of road; seeking for stone-quarries within his district; here and there building a small bridge across an irrigation canal, or replacing a few yards of dike that had been washed away by flood; above all, supervising these operations and keeping strict account of expenditure: such were the useful but monotonous and unscientific duties which for eight or nine years Fresnel faithfully discharged. One wonders what were the thoughts that filled his mind as he watched his workmen spreading stones along the highways, and rebuked dishonest contractors for exorbitance and bad material.

But a change came: like many another Frenchman of his time, wearied of war and of absolutism, Fresnel had great hopes that the restoration of the Bourbons would witness the dawn of political regeneration for France and for Europe. When Napoleon landed at Cannes in 1815 it seemed to him an attack upon civilization, and he hastened, in spite of physical infirmity, to join the Royalist army of the South. Napoleon was restored and Fresnel had to return to Nyons, almost dead. News of what he had done had preceded him and he became the victim of a thousand petty outrages at the hands of the excitable southern populace. Finally, he was forced into retirement to the place where he had spent his youth. Upon the second Bourbon restoration he obtained a post as engineer in Paris and

from this time until the end of his life date his contributions to science. The first paper was in 1815, and after that memoir succeeds memoir, discovery follows discovery, with a rapidity that has few parallels in the history of science. On December 28, 1814, Fresnel wrote from Nyons: "I do not know what is meant by polarization of light, ask M. Mérimée, my uncle, to send me works about it." Eight months elapsed and his researches in that subject placed him among the most famous physicists of his day. In 1819 he gained the Academy prize for his memoir on diffraction; in 1823 he became member of this body by unanimous vote. In 1825 the Royal Society of London admitted him as an associate, and two years later, as he lay dying, awarded him the Rumford medal.

Such was the homage of his contemporaries; it has been renewed by posterity.

Nearly all his works relate to the phenomena of light. Ignorant of the work of Thomas Young, he demonstrated the error of the Newtonian theory of the propagation of light by the emission of material particles, advocating instead an undulatory theory which he afterwards extended to a large class of optical phenomena. By an experiment with two mirrors set at an angle of nearly 180° , so that the incident beams reflected to the same point and showed alternate dark and light bands, he accounted for the phenomena of interference with the undulatory theory. With Arago he obtained circularly polarized light by means of a rhomb of glass ("Fresnel's rhomb"), which has obtuse angles of 126° and acute angles of 54° . His theory of the explanation of double refraction by biaxial crystals involving a most complicated wave-surface has stood the test of modern work.

To these theoretical researches Fresnel added an important application which has placed his name among the benefactors of mankind. This work was the betterment of lighthouses. Most people — unlearned in the art of navigation — experience some uneasiness when their ship far from land has for its only guide the stars and ocean currents. The sight of the most rugged shore dissipates, as if

by enchantment, their uneasiness, but the experienced navigator knows that then is when danger begins. There are some ports that can never be entered without a pilot, some even which cannot be approached by night, and such conditions render it essential that after sundown clear light signals must give warning of the proximity of land. The ancients have left many examples of famous lighthouses: for example, that erected in the reign of Ptolemy II to mark the harbor of Alexandria.

In actual height these great buildings exceed modern structures, but their lights, obtained from wood or charcoal fires in the open air on the summit, were feeble and often failed to pierce the fogs which in every climate prevail in lower atmospheric regions. Even up to the time of Fresnel lights were feeble, and much of them lost by dissipation. He was the first to construct compound lenses as a substitute for mirrors, adopting the annular or built lens. With Arago and Mathieu he made a large lamp having four concentric wicks, and this he surrounded by a frame of glass consisting of four or more annular lenses. The frame was made to revolve round the lamp, and thus the mariner gets the full force of the lens whenever its axis is pointed towards him, and the light gradually fades into darkness as the axis of the lens passes from him. To utilize the rays of light which passed above the lens, Fresnel used a system of double optical agents, a pyramid of lenses in the mirrors placed above at the proper angle for making the rays passing upward parallel to those which came from the annular lens.

By another invention he rendered the lenticular system practicable for fixed as well as for revolving lights. His lenses in this case were cylindrical, and showed a light of equal intensity all round the horizon, and to avoid any of the rays being wasted on the clouds or on the lighthouse floor, Fresnel introduced, above and below the cylindrical lenses, separate glass prisms of triangular section that by refraction and reflection bent upward and downward the escaping rays so as to make them horizontal and parallel to the others.

Fresnel died of consumption at Ville-d'Avray in 1827 when he was only thirty-nine. Arago, reading his eulogy before the French Academy of Sciences, began with the words: "*Il est des hommes à qui l'on succède et que personne ne remplace*" (he is one of the men whom others succeed but no one replaces).

CHARLES FRIEDEL

Who Planned the Chemical Laboratories of the Sorbonne

THE tomb of Charles Friedel at Montauban bears the inscription, with his name and date of birth and death (1832-1899), "*Membre de l'Institut*". And there is much significance in the way in which the simple title, member of the Institute, is used as the only record of occupation placed over his grave, for it is quite in accord with French usage to consider this distinction one of the highest that the nation can bestow. Thus Napoleon, in familiar letters having nothing to do with science, signs himself, "*Bonaparte Générale en Chef, Membre de l'Institut*". Friedel's love of science was hereditary. His father, also Charles, although beginning his long commercial life in a banker's office at the age of thirteen, attended scientific lectures at Strassburg whenever he had the opportunity, and at eighty-four expressed his regret that necessity had prevented him from following a scientific career, and the satisfaction that the choice had been offered his son.

Friedel took his bachelor's degree in letters in 1849, and that in science in 1850. He then entered his father's counting house, in Strassburg, and while there had an opportunity of attending lectures by Pasteur, Daubrée, Bertin, and Lereboullet at the university. His stay in the counting-house lasted only a year, for, as might have been expected, the attractions of science presented by such men drew him away from commerce. Accordingly he went to Paris to live with his maternal grandfather, the zoölogist, Duvernois. He took the licentiate degree in mathematics at the Sorbonne in 1854, and that in physical science in 1855. While pursuing these studies he began research work at the Museum in mineralogy, a science for which

his grandfather had inspired him with enthusiasm and which continued to be his favorite study for the rest of his days. All his students knew his weakness for a fine crystal or a new mineral. He followed the lectures of Sénarmont at the School of Mines and formed a strong personal attachment for him; and it was the latter who, in 1856, recommended his appointment as curator of mineralogy in the school, the important collection of which Friedel was ever after actively occupied in enriching. He was at first attracted by the crystallographical side of mineralogy, and then towards optics, until, at Sénarmont's suggestion, he thought of devoting himself to mathematics and becoming an astronomer. But soon the chemical side absorbed his attention, and during the remainder of his life his time was divided between pure chemistry and chemical mineralogy, although he always took special pleasure in the examination of crystalline forms.

In 1854 he entered the laboratory of Wurtz, and soon became his most distinguished pupil. This laboratory succeeded in some measure to that of Liebig, and was visited by chemists of all nations; for European science still held to the traditions of Humboldt, and a sojourn at Paris was considered a necessary part of a scientific education. His researches upon acetones and aldehydes were made at this time and his view of their constitution, and his discovery of secondary propylic alcohol, were immediately recognized as important contributions to chemical science. In 1866 the privileges of a small laboratory at the School of Mines were attached to the place of curator of the mineralogical collection, and it was there that Friedel's work on mineralogy was done as well as the work upon silicon compounds and the aluminum chloride reaction.

A dark vaulted cellar served for the artificial production of minerals at high temperature and pressure. Here Friedel and Edmond Sarasin heated "Jacob" to a very low red heat at whatever pressure boiling water gives at that temperature. The origin of the name is lost, but "Jacob" was the only designation of a

very heavy steel tube lined with platinum, in which water and pure materials intended to make silicates were heated overnight, and the fate of "Jacob" was a matter of lively interest each morning in the laboratory. There was no serious explosion, but any attempt to economize in the weight of the thick interior platinum tube led to disaster.

During the siege of Paris Friedel was shut up in the city, and in the service of his country. His wife and children had taken refuge in Switzerland, and the former died without his being able to see her again. In 1876 he was appointed professor of mineralogy at the Sorbonne and there he organized a laboratory for mineralogy. Two years later he was chosen member of the Academy of Science in the chemical section, filling the place left vacant by the death of Regnault.

The death of Wurtz in 1884 left Friedel the oldest representative of Wurtz's school, and he succeeded to the former's chair of organic chemistry at the Sorbonne. From this time he was in reality the leader of the school, directing successively the temporary laboratory, and after 1895, the new laboratories at the Sorbonne (built upon his plans). Beyond the personal researches of Friedel, much original work evolved from these laboratories and all nationalities were represented there. Roumanians, Italians, Russians, Serbs, Turks, Dutch, Belgians, Swiss, Portuguese, Norwegians, Americans, Englishmen, Austrians, even Germans (in spite of the recent war) did not disdain to work under him. He instigated the municipal government of Paris to create a three years' course of lectures and laboratory instruction in industrial chemistry at the provisional laboratories. With Wurtz he founded and edited the "*Dictionnaire de Chimie pure et appliquée*", and after Wurtz's death continued the work on the supplements (of which the second has only progressed as far as the letter "G"); he was one of the founders of the French Chemical Society, four times its president, always a constant attendant at its sittings, and he took the initiative in founding the French Society for the Advancement of Science in 1885.

STAFFS OF LIFE OF THE TEMPERATE ZONE



WHEAT AND ITS COUSINS THE BEARDED BARLEY AND SPANGLED OATS

The plant shown below is the corn marigold. This photograph is by Henry Irving.

IN PRAISE OF PLAIN BREAD

An Examination of the Cereals, and a
Comparison of their Different Food Values

WHEAT AS THE WORLD'S CHEAPEST FOOD

ABOUT the value of milk as an article of human diet, as we have seen, there can be no doubt, and it deserved a place by itself before we plunged into the welter of dietetic controversy. Almost as much may be said for bread, which is indeed "the staff of life".

Considered as foods, milk and bread are exceedingly different, above all because one is an animal and the other a vegetable food. Now, a great argument in favor of vegetable food in general is its extreme cheapness when compared with any kind of flesh, or even with cheese and milk. In round figures, speaking generally, the cost of vegetable nutriment is about one-fourth that of animal. Foremost among vegetable foods are the fruits or seeds of certain grasses called "cereals". Astonishing, indeed, is the dependence of mankind as a whole upon grass. Now, the most important of all the grasses is wheat, at any rate as far as Western civilization is concerned, and this we usually consume in an elaborately prepared form as bread.

The question of cost is worth close attention. It directly affects every individual, and it is a national matter also, for to discover and obtain the best and cheapest food supply for a nation is a task of the highest kind. But these questions of the cost of food cannot be decided by the amateur, and, indeed, the expert is apt to be content when his inquiry has by no means gone far enough. At any rate, we shall here ignore mere weight of the food or alleged food under discussion, and shall look only at the weight of the actual nutriment which it contains.

This, however, is not sufficiently precise, for we require to distinguish between the different types of nutriment; and it is fair to look at the proteins alone, these being absolutely necessary for life. But even in terms of proteins, as distinguished from nutriment in general, wheat flour is still the cheapest of all foods; and bread, though much dearer than flour, is still much cheaper than milk, meat or eggs.

It has been suggested that we pay the baker very heavily for his trouble, and that, so far as economy is concerned, it would be well worth while to bake at home as our forefathers — or rather, our foremothers — did, but if we consider the fuel, which at the present time is a large item, and the labor and attention necessary to produce good bread, we may conclude that the baker is not paid too much for his trouble after all. Then again there is the question of quality. A great deal of home-made bread is not good, although few housewives will admit this. They will claim that the same thing is true of baker's bread, which is the case, but the bakers as a whole have greatly improved their methods in the last decade and are using better materials. Although there is still room for improvement, the quality of baker's bread in general will average better than that made in the home.

It cannot be said of bread that it is a perfect food for man. In fact, there is no such thing as a perfect food — that is, a single food that will entirely take the place of an ideal mixed diet — but it should and does occupy a high position in the foods of all civilized nations. Bread

contains an excess, then, of energy-producing food, in proportion to its proteins, from which alone living tissue can be recreated. We need somewhat more fat than the proportion in bread supplies. This is the reason that we make bread puddings with eggs and milk, and eat bread with cheese, or spread it with butter, and it is frequently advocated that in the manufacture of white flour the most nutritious part of the wheat is sacrificed. To retain this, however, means the inclusion of the bran and germ which, according to many investigators, is open to question, as there is considerable difference of opinion about the digestibility of these products. When the germ is added in the natural form it turns rancid during warm weather and, like the bran, attracts insects of various kinds, so that the spoilage of graham and whole-wheat flours runs very high, resulting in a great deal of loss and causing annoyance to all concerned. It is therefore apparent that if any of the wheat coating is included in the flour at the time of milling, it must be subjected to a baking temperature long enough to sterilize it sufficiently to prevent loss from rancidity and render it less attractive to insects, which is impractical under present conditions. It is true that this part of the wheat is considerably higher in protein, the most valuable part of the bread, but exhaustive digestion experiments conducted a number of years ago seemed to indicate clearly that the highly nutritive material contained in the bran and germ was so protected by cellulose that the digestive juices were prevented from acting upon it and as a consequence a very large proportion was entirely lost.

The public, however, has its own ideas on these subjects and shows a decided preference for white bread in spite of the efforts of many writers and scientists to the contrary, and as the baker and miller must depend on the public for their business, they naturally do the best they can to supply the demand. If it was for a whole-wheat flour containing all the bran and germ, both would be glad to supply that; in fact, nearly all bakers now make whole-wheat bread to some extent.

The disadvantage of an excess of moisture in bread

Exactly what color to aim at is a further question, but meanwhile we may note that the moisture of the loaf is not without importance. A little over one-third of an average loaf is water, and, surprised though we may be at the large proportion of water in bread, we should remind ourselves that, even so, it is much less watery than raw meat. We must note further, in relation to the color question, that a brown bread is a moister bread; and the purchaser of a brown loaf is buying such an excess of water that, all told, he gets considerably less protein and less starch for a given cost, even though the brown flour does certainly include some of the valuable parts of the wheat which the white flour omits. This point about the excess of water is unfamiliar to most people, and it entirely upsets the usual assumption. Of course, it does not apply to the choice between the purchase of white or brown *flour*, for those who make their bread at home.

The superiority in all respects of crust over crumb

This water question further leads to the conclusion that the common opinion regarding the crust and crumb of bread is also erroneous. The crust is very much superior on all counts without exception, chiefly because it is so much drier. Only to consume the crumb of a loaf involves very great waste indeed. There are thus more reasons than one why we should make a point of eating our crusts, though the term "dry crust" is used almost as if it were equivalent to "dry husk". The crust is dry because it contains so little water, which is another way of saying that it is in proportion more valuable. Also, it is very good for our teeth, and for our children's teeth. One reason why our teeth decay is that we do not use them, an explanation entirely satisfying to the biologist, who knows that effort is the law of life, and that every organ, tissue or function which has its work done for it inevitably degenerates.

Why the crust of the loaf is more digestible than the crumb

Yet further, the crust of bread is much more digestible than the crumb, chiefly because it requires to be chewed, and is thus thoroughly mixed with saliva, which has all the better chance of doing its work because so little water is present in the first place. This is the sufficient reason why new bread, which is simply wetter bread, is less digestible. In a little while most of the water evaporates, and the task of digesting the bread is then simplified. It must be remembered that bread consists very largely of starch, the digestion of which is begun by the saliva of the mouth, but for which the stomach itself produces no ferment at all. If starchy foods are not properly mixed with saliva they simply get in the way in the stomach, and make no chemical progress until they reach the bowel.

The highly nourishing properties of toast, rusks and crackers

It should be added that cooked bread or toast is more digestible and no less nourishing than ordinary bread, this being still truer of the kind of toast called rusks. Crackers, also, are highly nourishing in proportion to their weight, for they contain very little water, and the constituents added to the flour in making them are themselves valuable. Three pounds of crackers are estimated to contain as much nourishment as five pounds of bread. Needless to say, these observations are all double-barreled. They tell the economist and the emaciated what especially to employ, but they also give the too stout man hints as to what he should avoid.

Until recently, many people believed in graham as against white bread. For the moment we here confine the discussion to these two, not dealing with "germ" breads, or any bread made of cream-colored flour. The principal feature which distinguishes real graham bread from all other is its inclusion of the bran. But the bran mainly consists of cellulose, which the human body does not digest

in any appreciable degree, and this indigestible cellulose incloses (and therefore preserves) the other constituents of the bran. Two dogs and a hen between them were found to be unable to deal with bran effectively; and this experiment suffices to explain the fact that there is really no relation between the percentage composition of entire-wheat bread and its nutritive value.

We live not by what we eat, but by what we assimilate. In this case, the cellulose is not only indigestible in itself, but a cause of indigestibility in other things. Thus the protein of graham bread is not absorbed as it should be, and even other foods, such as milk, when taken along with it, have their absorption interfered with.

Some doubts about the arguments for brown and entire-wheat breads

The fact is that the arguments in favor of entire-wheat bread as against white bread were based merely upon chemical composition, and should have had regard to the behavior of the bread in the bowel. The former medical practice of recommending the use of entire wheat bread by growing children and nursing women must therefore be abandoned. If entire wheat bread and entire wheat crackers are now to be regarded as having any special virtue, apart from their pleasantness to many palates, it is that the bran they contain is somewhat of a stimulant to the bowel, so that they may be commended in constipation, in some but not all cases.

Brief reference has already been made to the importance of properly mixing the saliva with the bread one eats. The importance of mastication, upon which all recent dietetic and dental authorities insist, is very marked in the case of bread. It is largely because toast and crackers and stale bread and crusts are dry that they are so useful. The teeth can work upon them, and they soak up the saliva, neither of which statements is true of new bread. Also, in the stomach, crackers are found to be much more digestible than ordinary bread, and stale bread than new bread.

The greater likelihood of a mixed diet giving the body what it wants

As a general rule vegetable foods are much less well absorbed than animal; but on the whole, and compared with other vegetable foods, white bread is extremely well absorbed — best of all when taken with other kinds. Indeed, everything goes to show that not only is man best suited by a mixed diet, but that, at any rate in health, he profits best by a mixture of foods taken at any one time. Much of the salts of bread, including its iron, is unabsorbed; and an increase of the proportion of salt by the use of the bran of the grain is probably merely an increase in what is swallowed, not in what is used. In modern milling the object is to obtain as much flour of good appearance and quality as possible and to diminish the yield of bran and shorts to a minimum. Graham flour is unbolted wheat meal ground from the whole kernel. Whole or entire-wheat flour contains all the kernel except a portion of the bran. The patent and clear grade flours contain the endosperm and very little of the bran, germ and embryo.

We have finally decided in favor of white as against entire-wheat flour. But so-called white flour may and does vary very widely in composition — a fact to which doctors have been drawing attention for many years. Inquiry has been specially directed to the difference between the various grades of white flour, and the opinion has been abundantly confirmed that the higher gluten or protein wheats of the Northwest produce flours of much higher food value than the softer wheats. This type of flour should and does command a premium, not only for its higher nutritive value but its superior bread-making qualities.

Obscure qualities in foods that give them a special value

However, in the course of special study of this question of the kinds of flour, it was shown that what is now often called pure or "hard patent" flour has a superiority which is not to be explained

solely in terms of its excess of protein. If some such percentage of superiority were all it could boast, a slight increase in the amount of "patent" consumed would put things right. But that appears not to be the case. The fact is that these strong flours contain a substance, or perhaps a series of substances, which have a specific virtue of their own in relation to nutrition, but which are absent, or nearly absent, from the softer flour. We cannot name or define these substances nor can we allot them to any of the great classes of food-stuffs which we first found exemplified in milk — proteins, carbohydrates, fats and salts. But that merely shows how inadequate our knowledge of dietetics still is.

The fact is that this comparatively recent discovery regarding the wheat-grain is only one of a large number, all of which point in the same direction. The study of milk taught us that there are certain great classes of food-stuffs necessary or very desirable for health. But we also learned that there seem to be some obscure substances in milk that cannot be called foods, on the ordinary physiological definition, but yet are very desirable for health. Some time ago light was thrown on a long-mysterious disease called beri-beri. In India and Ceylon and other parts of the world certain people are suddenly taken with an illness which involves inflammation of the nerves, great weakness of the muscles, painful rigidity of the limbs, and general symptoms of poisoning. It looks as if they had been attacked by something comparable to the arsenic, lead, alcohol, etc., which are known to produce similar symptoms. No such cause could be found. A microbe or other parasite was long hunted for, without success. But now it has been proved convincingly that the symptoms are all due to the lack of something from the diet of the patient. He has been living almost exclusively on rice which has been "polished", the outer skin of the grain having been removed. But that outer skin contains minute traces of a chemical compound without which the disease called beri-beri will appear.

The mystery of scurvy and its equally mysterious cure

A far older instance, still obscure, is that of the well-known disease scurvy, which for a long time barred the path of mankind to the North Pole.

Here is a disease from which we are all prevented by something which we take in an ordinary diet, but which we cannot define, and which is not a food in the ordinary sense of the word, according to the long-accepted physiological definition which we shall shortly study. When sailors are deprived of fresh fruit and vegetables, though they are well fed on proteins and carbohydrates and so forth, they are liable to suffer from scurvy, a disease of nutrition which has its parallel in the "infantile scurvy" of improperly fed infants. But the regular supply of such a substance as lime-juice, which is not a food, and does not answer to any of the physiological ideas of a food, is sufficient to prevent the disease.

Such facts as these point to a realm of dietetics about which we know practically nothing as yet, but which must lead us to be very cautious in our assumptions, hitherto confidently made, that we can really estimate the value of any diet by making chemical analyses of the protein, etc., that it contains. All the time we may be overlooking some really essential ingredient, the existence of which can only be inferred from the disastrous consequences which follow its withdrawal from the diet.

Valuable forms of wheat that are known under other names

This is far too big a subject to be dealt with incidentally here, but we have already seen enough to make us realize that the supposed superiority of bread made from flour which includes much of the germ of the grain may not be as important as many believe, particularly when a mixed diet is available. Wheat is such an invaluable food-stuff that we should be acquainted with the various forms, other than bread and crackers, in which it is presented to us. These include

semolina, macaroni, vermicelli, Italian pastes, "shredded wheat", "Force" and "Grape-Nuts". Not every housewife knows that the first three mentioned are really wheat flour, and therefore rank specially high in the dietetic scale. There is an immense interval, for invalids and children and everyone else, between such substances and, for instance, arrowroot, a favorite invalid food of the past, which practically consists of nothing but starch, is scarcely worth eating at any time, and is certainly a mockery for invalids. As for the ready-to-serve preparations, these are all whole-wheat preparations, easily digestible, very cheap and highly nutritious.

Some of the relations, rich ones, of that prince of cereal food: wheat

Wheat, we have seen, takes first place among the cereals, but its relatives may conveniently be dealt with here also. Oats, for instance, are a very valuable source of food. Growing as they do in the north, they are somewhat rich in fat, for such a useful source of heat is required for the purposes of a young plant that is to grow in high latitudes. Thus, oats are rich in fat; while rice, which grows in warm climates, is poor in it. Hence, both on account of its fat and because of the irritant and innutritious husk, ordinary oatmeal is not a very suitable food for those whose digestion is delicate. The consumer of ordinary oatmeal porridge who finds his digestion troubling him should give it up. Some of the recent rolled oats, however, are more easily digestible, though the method by which they are prepared somewhat reduces the nutritive percentages in the product. By those whose digestion is good, oatmeal porridge is very well absorbed.

Another excellent cereal, Indian corn, agrees with oats in not containing the glutinous ingredient by which wheat flour can be made into bread; but "johnny cakes", which form an important part of the diet in certain sections, do not compare very well with white bread made from the strong wheats on account of a much lower protein content.

Barley is another important cereal which is of very considerable nutritive value, though it is inferior to wheat. Loaves made half and half of wheat and barley-meal are an excellent article of diet, however. There is no appreciable nourishment in barley-water, which is, nevertheless, an excellent drink in its way.

Last, but not least, in this list of the cereals comes rice, the grass which supplies food for more of mankind than any other; indeed, it is said to be the staple food for one-third of our species.

Though it agrees with the other cereals in general, it is distinctly inferior to them. We have already seen that it is relatively poor in fat, of which the young embryo needs less in a hot climate. But it is also very poor in protein—say about one-third as well provided in this respect as wheat. Indeed, we have to look upon rice as mainly a starchy food, barred, of course, to infancy. This also means that, for a proper diet, rice must be supplemented by other substances, richer in the protein or nitrogenous constituents.

Rice, no doubt, has its virtues, especially when it is understood. It is best cooked by steaming. The Italians, into whose country rice was introduced a few centuries ago, do well to eat it in the form of what they call "risotto", for then they take eggs and cheese with it,

which supply its relative defect in proteid. But, at its best, rice cannot be compared with wheat, easily the first of all cereals.

Apart from a proper supply of milk, a proper supply of wheat flour is an essential for the healthy life of any modern nation. We have seen the evidence that this food occupies a special place, in virtue of its richness in the most valuable ingredients of a diet, both those known and those unknown, and in virtue of its remarkable cheapness in proportion to its nutritive power; and we may add that it is also to be valued for the absence of any ingredients which are poisonous or dangerous, nor is it liable to contamination or infection.

And our scheme of national education should comprise courses in domestic science with its study of food-values. Girls should be taught cooking and baking; and these subjects should be associated with the study of domestic economy in relation to food-values. The cause of health would be greatly served by just such a simple reform in education as would teach the women, and especially the mothers, of the nation to spend their money more on wheat and its products and less upon the inferior cereals, to say nothing of meat, which yield no such nutritive return as wheat for a given expenditure.



Courtesy Canadian Pacific Railway

A LIMITLESS HORIZON OF WHEAT
Train of reapers at work in Alberta, Canada.

THE MIGHTIEST FORCE

How the New High Explosives are
Changing the Face of the Earth

THE WEAPON OF DEATH A SOURCE OF LIFE

OF all the forces over which mankind has obtained control, there is none so mighty and so useful as fire. Yet fire as we commonly know it is but one of a large number of similar phenomena which occur when oxygen combines with other substances. When a tree decays, the oxygen of the air combines very slowly with the organic matter of the tree — it is an affair of years. When a piece of iron rusts, again the oxygen of the air is combining with the metallic iron, and it takes weeks and months. In a burning grate the union of coal and oxygen is quicker — a matter of minutes. In the case of gunpowder or the high explosives used in modern industry and modern warfare, the speed with which oxygen enters into a chemical reaction is practically instantaneous. For instance, in dynamite, the wave of explosion travels at a pace of more than 5000 yards a second. A foot of dynamite explodes in one-24,000th of a second. A mile of dynamite cartridges blows up from end to end in one-fourth of a second; and a much greater speed of reaction occurs in cotton dipped in nitric acid and mixed with glycerine that has also been nitrated.

Chemists have given the name "oxidation" to the type of changes or chemical reactions which result from the tendency of oxygen to combine with other substances. As the few above examples have shown, oxidation reactions are by far the most important type of chemical changes. What we wish to discuss here, however, are only the more rapid kinds of oxidation which take place in the firing of a gun or in an explosion.

Almost any substance that will burn can be made into an explosive by making it possible for oxygen to combine with it very rapidly. Thus coal in a pile oxidizes very slowly — it would take thousands of years to consume the whole pile if it were kept cool. Once heat it up, which makes the oxygen combine more rapidly, and it will give a bright, warm fire. Blow air, or better yet, pure oxygen into the mass, and it will give a dazzling white heat. Even yet we have no explosion, because it takes too much time for the oxygen to get to the coal. If, however, the coal be powdered extremely fine and mixed with the proper amount of air, it will explode violently when ignited, because each minute particle of coal is now surrounded by oxygen, and can combine with extreme rapidity. Many of the terrible accidents in coal mines are due to this kind of explosion.

Such mixtures of gases and solids would, of course, not be satisfactory for use as military or industrial explosives, since they could not be stored or transported. If, however, we mix finely powdered coal, or better, charcoal, with saltpeter, a solid substance which contains three thousand times as much oxygen (in a given volume) as does air, we have something which could serve as a commercial explosive, since the oxygen and the inflammable material are both in solid form, and yet mixed together very intimately. Each particle of charcoal has its particle of oxygen right at hand in the saltpeter, so that the two can combine with explosive rapidity. These two substances are the basis of ordinary black powder.

Two factors combine to produce the mighty force of an explosion. The first is the fact that the solid explosive, occupying a small volume, is suddenly transformed by oxidation into a huge amount of gas. Thus a cubic foot of nitroglycerine weighing one hundred pounds is changed in a fraction of a second into gases which, when cooled to ordinary temperatures, would occupy more than a thousand cubic feet.

More important even than this, however, is the fact that an explosion sets free a large amount of energy in the form of heat, which heats up and expands the gases to a much greater extent. Probably the gases from the hundred pounds of nitroglycerine, when heated to the tem-

Such is the simple explanation of the production of the greatest force of modern times. A petroleum lamp burns steadily and slowly by reason of the small supply of air that it obtains. If the air is mixed quickly with the oil, an explosion occurs that can be so regulated as to drive an airplane at the rate of a hundred and seventy-five miles an hour. The automobile is merely a machine for transmitting the regulated power of explosion to wheels. The modern gas engine also derives its power from explosions of gas and air. In all these cases, the oxygen of the atmosphere is intimately combined with oil or gas before the chemical reaction provoked by heat is set up. So, instead of a slow combustion, there takes place a rapid pro-



Courtesy U. S. Bureau of Mines

EXPLOSION OF COAL DUST AND GAS IN THE UNITED STATES TESTING GALLERY AT PITTSBURGH

perature which prevails immediately after an explosion, would occupy more than ten thousand cubic feet. At the instant of formation the pressure of the gases is likely 200,000 or 300,000 pounds per square inch—a thousand times as great as the pressure which would burst an ordinary steam boiler. This sudden liberation of a large amount of gas at a high temperature and under an enormous pressure is responsible for all the effects of an explosion. Any container is instantly shattered; a rock or a stump in the path of the expanding gases is swept away like a straw by the wind. The wave of air pressure which spreads in all directions breaks windows and rocks houses even at great distances.

cess producing a sudden and violent expansion of gases. The gases strike against the piston of a cylinder and shoot it forward. In this way the motion necessary to drive the wheels of an automobile or the propeller of an airplane is obtained. In other words, a great deal of the machinery in mills and factories and workshops where a gas-plant is used is harnessed to the terrible chemical forces that we hear of in their most sensational forms in connection with war.

Though gunpowder was invented by the Arabs in the thirteenth century, and introduced into Christendom by Roger Bacon about 1270, fifty-eight years before Berthold Schwartz, of Freiberg, described it, the industrial use of explosive power

CHEMICALS DISCOVERING CHEMICALS



BORING TEST-HOLES IN THE NITRATE FIELDS OF CHILE



BREAKING UP THE SOIL BY BLASTING A CHARGE PLACED IN A TEST-HOLE

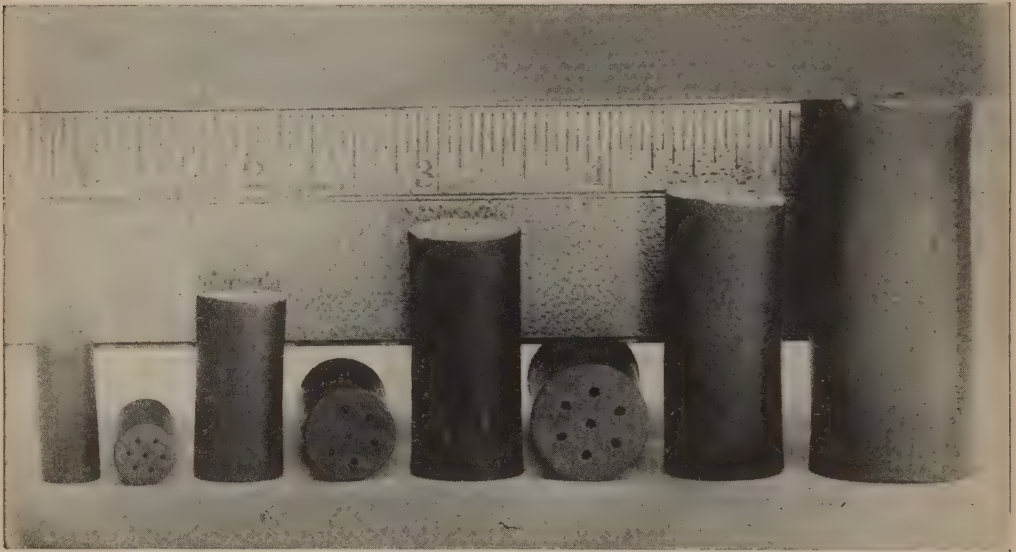


CRUDE NITRATE, OR "CHILE SALTPETER", BROUGHT TO THE SURFACE BY THE EXPLOSION

was neglected for centuries. The science of road-making and mining was scarcely more advanced in the age of Shakespeare than it had been in that of Virgil. Gunpowder seems first to have been employed in mining in 1613, when Martin Weigel, a mine manager at Freiberg, began the excavation of ore by drilling and blasting.

Till about fifty years ago gunpowder remained the greatest force that man could safely use. In the arts of peace and war alike, a mixture of charcoal and saltpeter, to which was added a certain amount of sulphur, produced the expan-

nitric acid, and produced nitroglycerine, which won a tragic notoriety under the name of "blasting oil", for it was a very delicate chemical compound and exploded with the least shock. Being liquid, it ran into the fissures of rock when poured into a borehole; and it required to be carefully confined when exploded by means of a simple fuse. Accidents occurred so frequently that its use was prohibited in several countries and when a ship carrying some of it to Chile was blown up, the event caused such a sensation that it seemed as though the use of nitroglycer-



GRAINS OF SMOKELESS CANNON POWDER

The grains of powder used by the United States government for guns of large caliber are in the form of cylinders with seven perforations running lengthwise through them. When ignited, the perforated grains, being very hard and dense, burn in parallel layers, the exterior with a decreasing, the holes with an increasing surface.

sive gases with which man killed and dug and tunneled. The United States army standard black powder, which was used almost exclusively until the Spanish-American war, consisted of 75 per cent saltpeter, 15 per cent charcoal and 10 per cent sulphur. As a matter of fact, however, a series of more powerful explosives had been discovered by modern chemists. In 1832, Braconnot transformed starch into a source of terrific power by treating it with nitric acid; six years afterwards, Pelouse and Dumas changed cotton and paper into guncotton and gunpaper by nitrating these substances. In 1846, an Italian, Ascanio Sobrero, treated glycerine with

ine would be forbidden throughout every civilized country in the world.

But a Swedish chemist, Alfred Nobel, solved in 1866 the problem of the high explosive. He mixed nitroglycerine oil with a certain kind of porous earth, and produced a stuff somewhat like sawdust, which he called dynamite. Twice as powerful as gunpowder, and much more reliable, dynamite entirely revolutionized the science of blasting. It made possible the execution of the gigantic engineering works of our period, and it brought about that prodigious development of the mining industries of the world which has gone on since 1870.

A POWER THAT REMOVES MOUNTAINS

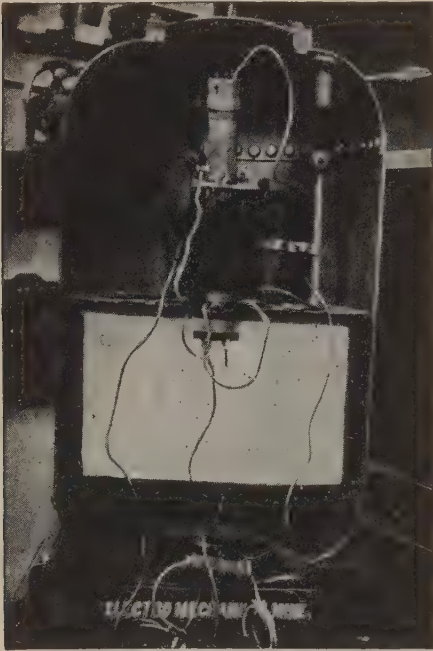


BLASTING AWAY A HUGE MASS OF CLIFF IN RAILROAD CONSTRUCTION



THE DEBRIS RESULTING FROM THE EXPLOSION SHOWN IN THE PICTURE ABOVE

In fact, the invention of dynamite marked an epoch in the history of civilization. It enabled man to change, in a single generation, the face of the earth. By means of it he flung a network of railroads over the continents; he removed mountains from his path; he mined for miles into the fiery heart of his planet; he joined oceans together by blasting away the rock and earth that sundered them; and, last of all, he threw aside his plow and all his steam machinery, and did his farming work with dynamite.



INTERIOR OF A SUBMARINE MINE

The white space is occupied by the explosive, which consists of seventy-five pounds of guncotton

In the ordinary way, dynamite may be kicked about and set alight, and even fired from a gun without exploding. So, too, a considerable quantity of guncotton may be set on fire, and it will then burn quietly. A torpedo filled with wet compressed guncotton will not go off, though a shell from a big gun penetrates the torpedo and bursts in the mass of guncotton. Even nitroglycerine will burn like oil in small quantities, and a stick of nitrogelatin may be lighted without danger.

Many persons, unfamiliar with modern explosives, imagine that shells and submarine mines and blasting compounds are

dangerous in themselves, and that to handle any of them would be playing with death. But really the only ticklish part of the affair is the fulminating body, made by dissolving mercury in nitric acid, and adding alcohol to the solution. This is the "setting off", and when it is attached to a high explosive death is very close at hand.

The real trouble with dynamite, from a modern point of view, is that it is not sufficiently explosive. It is safe, because a fourth part of it consists merely of absorbent earthy material which plays no part whatever in the generation of the gases. Formed of the remains of diatoms—a microscopic sea-plant with a hard shell—this material is inactive, and it takes away greatly from the power of dynamite. Knowing this, Nobel sought for some years for an active base for his nitroglycerine compound. He wanted a substance which would dissolve in nitroglycerine and form a certain kind of chemical paste.

One morning he was still experimenting in search of the new material when he cut his finger. He sent a man out for some collodion to form an artificial skin to protect the wound. Having used a few drops as a liquid plaster on his cut finger, he was going to throw the rest away, when he thought of trying a mixture of collodion and nitroglycerine. Collodion is made by dissolving guncotton in ether, and the solution so formed is used as a liquid plaster and a varnish and for photographic purposes. When combined with camphor, the dissolved guncotton becomes celluloid. Only moderately strong nitric acid is employed in making this commercial kind of guncotton; it is often highly inflammable, but the camphor makes it inexplosive, and it can be worked with hammers and heavy rollers without any risk. By omitting the camphor, Nobel obtained a mixture of guncotton and nitroglycerine which was remarkably safe, and yet remarkably powerful.

Only the accident of cutting his finger could have led the inventor to experiment with guncotton, for this explosive was the deadliest and most useless of blasting compounds. Guncotton contains too

BLOWING UP DANGERS TO NAVIGATION



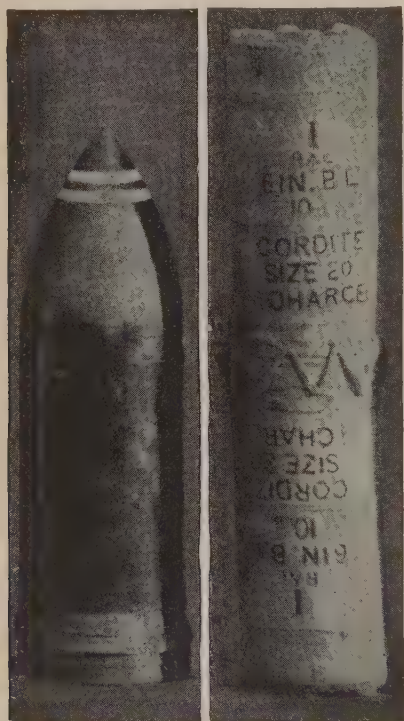
Photo West & Son, from Philip's "Romance of Modern Chemistry"

WHAT MODERN HIGH EXPLOSIVES CAN DO

A wooden boom has been blown up and completely disintegrated by a torpedo. Note the immense body of water raised by the force of the explosion.

little oxygen for combustion. The consequence is that when it explodes it gives off poisonous fumes. Thus it was impossible to use it for industrial purposes. Nitroglycerine, on the other hand, contains an excess of oxygen. So when Nobel combined the two explosives in certain proportions, the element that was wanting in one was supplied by the excess contained in the other.

The new explosive was half as strong again as dynamite, and it has been used in large quantities in piercing mountains



THE PROJECTILE AND CORDITE CHARGE
OF A 6-INCH GUN

like the Alps, where the rock is so hard that no satisfactory work can be done without it. Blasting gelatine is one of the most violent forces at the disposal of the human race. In its pure form it can be applied only to the hardest rock. Nobel, however, soon found a way of modifying its terrific action by adding saltpeter and woodmeal to the mixture of nitroglycerine and guncotton. At the present time the use of dynamite has been entirely superseded in some countries by gelatine explosives.

The application of the new high explosives to purposes of modern warfare

It took many years to learn how to apply the new high explosives to the purposes of warfare, and before gunpowder was displaced by the stronger nitric acid preparations in artillery. Even when blasting gelatine was reduced in power by means of moderated substances, it could not be made to fire a gun. So abruptly rapid was the creation of gases that they burst the cannon, instead of driving the shell from the muzzle.

In fact, two different types of explosives are needed for military purposes, known as "propellants" and "high explosives". The propellants are used in rifles and big guns to give a long, steady push to the bullet or projectile, and hence they must not explode too rapidly. The high explosives are placed inside the shells so as to burst them into fragments just over the heads of the enemy. They must therefore explode very suddenly to give a shattering blow, even more violent than that needed in blasting.

The most important component in almost all of the propellant explosives used in modern warfare is guncotton, or nitrocellulose. This is made by treating cotton, or sometimes other substances, such as wool, jute, straw, starch, sugar, etc., with nitric acid, in a manner which will be described later. In its ordinary state guncotton is too unstable and too rapid an explosive for use in guns. Inventors in various countries have therefore modified it in a number of ways. The first form successfully used in a rifled firearm was one invented by a Frenchman, Paul Vieille, and in 1884 adopted by the French government under the name of *Poudre B*, the initial being that of General Boulanger, then Minister of War.

Poudre B was made by adding some solvent to the guncotton, which partly dissolved it and made a doughy mass. This was squeezed out through dies of various shapes, forming ribbons or sticks which were cut into short lengths. When the solvent was evaporated off it left hard, dark brown pieces which burned slowly enough to make a satisfactory propellant.

DROPPING DESTRUCTION FROM THE SKIES



Photo Pacific & Atlantic Photos, Inc.

UNITED STATES ARMY AIR SERVICE BOMBING A VILLAGE

This "stunt" was staged to entertain the Shriners at their convention in Washington in 1923, reproducing a frequent scene in the Great War.

Warships destroyed by the new smokeless powder

This mixture has since been modified in a number of ways, especially by adding substances to make it more stable, and trying out different solvents. If acetone is used, the pieces are rather brittle, and a mixture of ether and alcohol is therefore more frequently employed.

This *Poudre B* earned a most unpleasant notoriety by the large number of accidents that it caused, especially the total destruction of two of France's best battle-ships, the *Jéna* in 1907 and the *Liberté* in 1911, catastrophes the more striking in that they occurred in Toulon harbor, in sight and hearing of the whole city. Indeed, before the *Jéna* disaster there had been twenty-four cases of spontaneous ignitions of *Poudre B*. The knowledge of these accidents prevented many of the other countries from adopting this form of smokeless powder. The French, Russian and United States governments are the only ones which now use straight guncotton explosives for all types of guns. It is, however, used in small guns by all the great powers except England and Italy.

When it was found that the guncotton was liable to decompose with such disastrous results, chemists in France, Russia and the United States set to work to find the cause of this decomposition and the means of preventing it. Their combined efforts resulted in many improvements in the methods of cleaning the cotton, nitrating it, and carefully washing all the acids out of the guncotton. They also found that it was desirable to treat with fresh solvent any powder which was over three or four years old. With these precautions it is believed that the nitrocellulose smokeless powders are as safe as any which could be used, and this type is used exclusively by France, Russia and the United States for all sizes of guns. All the powers but England and Italy use it in small-bore guns and rifles. It has the great advantage that the wear on the guns is not nearly as much as is the case with other powders.

Relative advantages of cordite and other explosives

The British government has, however, never been convinced that straight guncotton explosives are as safe or desirable as the cordite which they have developed from another discovery of Alfred Nobel. He found that in spite of the fact that nitroglycerine is far too shattering an explosive to be used in guns, a mixture of about 50 per cent of nitroglycerine with gelatinized guncotton made a very satisfactory explosive. Abel and Dewar of the British government worked out the following process for making it: The guncotton and nitroglycerine are mixed by hand, dissolved in acetone to form a paste, kneaded for several hours by machinery, with the addition of vaseline, and then the paste is forced through a spaghetti machine to form long strips or cylinders. For this reason it was called "cordite". For many years it consisted of 58 parts nitroglycerine, 37 parts guncotton and 5 parts vaseline. In the Boer War, however, it was found that the wear on the guns was so very excessive that the composition was changed to 30 parts of nitroglycerine and 65 of guncotton. Even in this form the life of their big guns is only about half as long as ours, which use straight guncotton, but the British believe that this is compensated by the greater cheapness, dependability and safety of the cordite powder.

Both these types of powders are known as "smokeless powders" because they leave no solid residue, but are completely changed into gases. These new propellant explosives have revolutionized the conditions of warfare on sea and on land. When fired, they produce no smoke to cloud the scene of battle, and they drive bullets and shells to a distance undreamed of by riflemen and gunners of the old school. Naval guns are now in use which can throw at every broadside five and a half tons of steel to a distance of twenty-one miles — often striking forts and ships which are so far away as to be invisible to the men on the battleship itself. The fire is of course directed by men in airships.

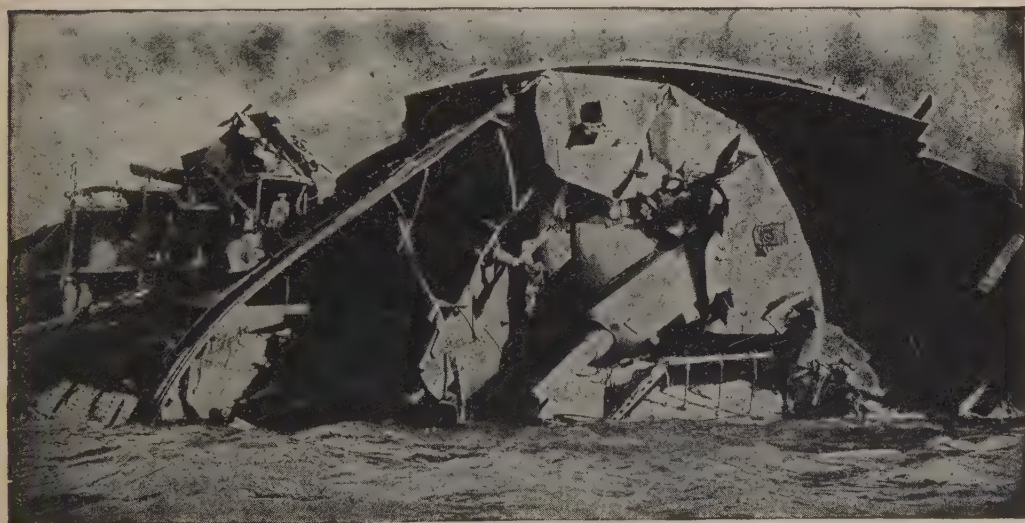
TERRIBLE EFFECT OF HIGH EXPLOSIVES



THE FRENCH BATTLESHIP *LIBERTÉ* OF 15,000 TONS



THE EXPLOSION DUE TO DETERIORATED GUNCOTTON THAT BLEW HER UP



THE CRUMPLED WRECK IN TOULON HARBOR AFTER THE EXPLOSION

Even more terrible than these propellants are the high explosives which are used to burst the shells. The substances used for this purpose must have two rather contradictory properties — first, they must not explode from even such a violent shock as the explosion of the charge of propellant which sends the loaded shell on its long and rapid journey; and second, when the time fuse burns to the end, they must explode instantly and with such violence as to shatter the shell to bits over the heads of the enemy. There are naturally not many substances which fulfil both of these two requirements.

A common coal-tar dye used as a high explosive

Picric acid is the one high explosive most used until recent years. The French melenite, the Japanese shimose and the British lyddite are all composed chiefly of picric acid. It is a coal-tar preparation, frequently used for dyeing, since it gives a bright yellow color on cloth. It was for many years used as a dye before its explosive properties were known except by a few scientists. A terrible explosion in a Manchester dye house first called popular attention to its dangerous properties. Picric acid can be melted to a clear, yellowish liquid which looks much like honey, and can be poured directly into the shell, where it solidifies. The fulminating body at the end of the fuse is almost the only thing which will set it off.

Recently there has been developed a new and better explosive known as tri-nitro-toluene. This is also a coal-tar product of very similar composition to picric acid. Although the tri-nitro-toluene, known the world over as T N T, is a more violent explosive than even picric acid, it is nevertheless the safest to handle of any of the common explosives. Yet when a giant shell loaded with T N T reaches the proper place in its flight, and explodes, there is a literally deafening report, and when the cloud clears away the very face of the earth is seen to be changed. A huge crater is dug in the earth, trees are uprooted and the hardest rocks are ground to powder.

How explosives are made and some of the safeguards used to protect the makers

Since the majority of explosives used for military and industrial purposes consist of nitroglycerine, guncotton, or mixtures of the two with other substances, it will be of particular interest to describe their method of manufacture somewhat in detail.

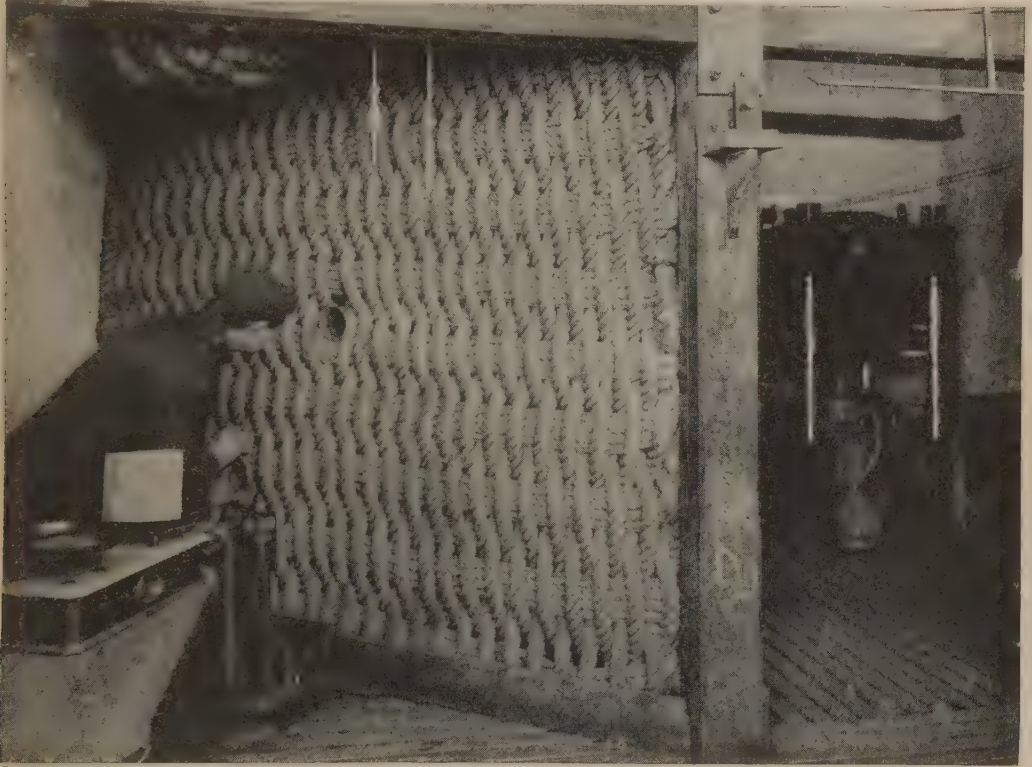
In the United States guncotton is made from the short cotton fibers picked off seed of the cotton as it comes from the gin. In England they use chiefly the clippings and waste from cotton mills. The stuff is first picked over and cleaned from oil and grease and dirt, and then carded and cut into short lengths. After this, it is well washed and dried in steam-jacketed cylinders, about five feet long and one and a half feet wide. The dipping is done in cast-iron tanks, holding about twelve gallons of strong nitric and sulphuric acids. The sulphuric acid does not add in any way to the explosive power of the guncotton. It is used merely as an absorbent, to prevent the water, which is formed during the process, from weakening the nitric acid, and this allows the real explosive elements to expand into gases without any lessening of their strength.

The cotton is thrown in the tank a pound at a time, and moved about by the workmen with an iron rabble. When thoroughly wet, it is lifted on to a grating above the tank, and there it is squeezed until it only contains about nine times its weight of acids. That is to say, a pound of cotton after being dipped should weigh ten pounds.

The steeping process has then to be carried out. The dipped cotton is placed in earthenware pots, which are set in rows in large cooling-pits, a foot deep, through which water is kept running. For forty-eight hours the cotton remains in the pots, and great care has to be taken to keep it quite cool. If all goes well, the chemical reaction is completed at the end of two days, and the cotton is entirely transformed into a new chemical compound, which is called "nitrocellulose".

Guncotton is one of the least dangerous of the nitro compounds to manufacture. It is often drained in a whirling machine that makes from a thousand to fifteen hundred revolutions a minute; and it is pressed by hydraulic power into blocks weighing a quarter of a ton, for use in torpedoes and submarine mines. A good many people now comb their hair with guncotton and handle it at all their meals. For, as we have already explained, two

buildings placed in a danger area. The buildings are at different levels, down which the liquid explosive flows through lead-lined wooden pipes, from one house to another. No iron or steel or brick or stone is used in the construction of the danger buildings. They are made of wood, which offers much less resistance than hard material. Usually, when an explosion occurs, the sides of the house are blown out, and the roof goes up in the



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WORKING UNDER COVER

In the background is a guncotton press, and the workman in the foreground who operates the machine is protected in case of accident by the rope screen through which he is peering.

parts of liquid guncotton and one part of camphor form the celluloid out of which combs and knife-handles and innumerable other articles of daily use are manufactured. Yet when guncotton was first made in bulk, some dreadful explosions occurred in the factories, for a little pressure was sufficient to detonate the compounds.

The manufacture of nitroglycerine, however, is still a somewhat perilous operation. It is performed in a set of danger

air and tumbles back on the blown out walls. Had the explosion occurred in a strong brick or stone building, large fragments of the material would have been shot at the surrounding edifices. The best plan, it has been found, is to sink all the danger buildings in pits and surround them with ramparts of turfed earth, standing higher than the roof of the house of peril. In this way the effects of the disaster are confined to the spot at which it occurs.

In nitroglycerine works every effort is made to prevent any possibility of a slight shock, a scratch of metal against stone, or any such trivial disturbance which might set off the whole factory. The workmen must wear shoes of sewn leather, for nails are much more dangerous than lighted matches. All the tools are made of bronze or brass, and the buildings are kept together by wooden pegs or brass nails. Explosions have resulted from such slight causes as the action of sunlight on a bucket containing water which had been used in

explosive takes place in the nitrating-house, which is kept scrupulously clean of grit and sand and dirt. Through a window in a large tank of lead, the operator watches a stream of glycerine flowing into a mixture of sulphuric and nitric acids. Under his control is a current of compressed air, that keeps the liquids well agitated during the process of nitration. A thermometer indicates the temperature of the mixture, and the greatest care must be taken to prevent the heat produced by the chemical reaction from raising the



From Philip's "Romance of Modern Chemistry", and by permission of Oscar Guttman & Sons

A DANGER AREA

A dynamite factory in England. The scattered sheds for the various stages of the manufacturing process are separated from each other by earthworks, so that in the event of any explosion the damage is localized. The pipes convey water and acids to the separate sheds.

washing nitroglycerine. So, altogether, a worker in a nitroglycerine factory does not have a dull life. His conditions of work are being steadily improved, however, and the process is not nearly as dangerous as formerly. The workmen on entering must change all their clothes, and are not allowed to bring in any pieces of metal, matches, cigars or cigarettes. The nitroglycerine gets into the workmen's clothes and if he wore them home, he would be a sort of walking torpedo, liable to go off on the slightest provocation.

The first stage in the making of the

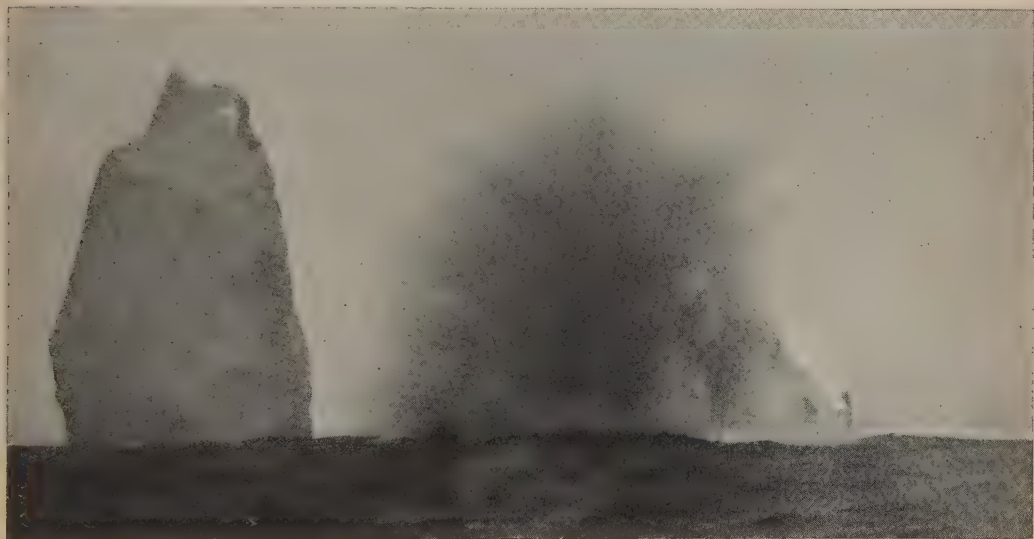
temperature beyond the danger point. A constant stream of water circulates round the tank and cools the mixture, and the current of compressed air also serves to lower the temperature. It takes about thirty minutes to complete the nitration; and when this is done the raw nitroglycerine is ready to run to the separating-house.

It is a heavy, oily liquid, of a pale straw color, with a sweet taste and rather poisonous qualities. Some persons cannot let it touch their skin without getting a headache, and unless it is kept cool it is liable to explode.

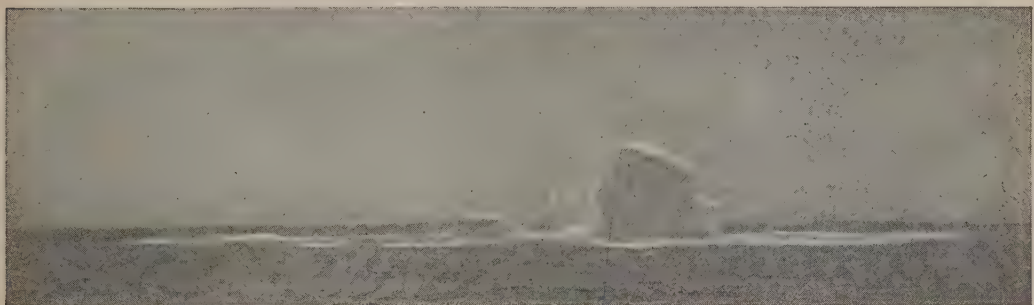
EXPLODING AN ICEBERG WITH TNT



Pulling away after attaching the mine to the 1400-foot berg.



The mine exploded by electricity from a distance of 700 feet.



"When the smoke cleared away only three small cakes were in sight."
U. S. COAST GUARD CUTTER *TAMPA* DISPOSES OF A DANGER TO NAVIGATION
Photos Lieutenant R. T. McElligott.

THE WORLD'S GREATEST POWDER PLANT



Panoramic view, in sections, of "Old Hickory", the United States government's huge smokeless powder by the Du Pont Engineering Co., which received as compensation the sum of one dollar. It was constructed by the United States prior to 1914, and the entire outfit seventy times as large as the biggest one of its cost than any other large war plant constructed for the government. It was planned to produce

BUILT FOR WAR TO BE USED FOR PEACE



plant, costing \$85,000,000, built in a bend of the Cumberland River, 18 miles from Nashville Tenn., struicted in nine units, each approximately eight times the size of the largest smokeless powder plant in kind in the world before the war. It was built in record time and came nearer the original estimate of 900,000 pounds of powder per day. It is now being turned to peace-time business enterprises.

The liquid, then, flows from the nitrating-house to the separating-house. Here it becomes very dangerous. The separating-tank is also fitted with a window; and as the waste acids run away from the nitroglycerine, a workman watches for the appearance of the vivid red fumes which are the danger signal. Whenever the smoke grows red, the pressure of compressed air must be increased to mix up the charge that is getting too hot through chemical decomposition. This decomposition is provoked by the water, with which the nitroglycerine is washed two or three times. If the fumes cannot be kept down, and an explosion is likely to occur, the tap between the separating-tank and the drowning-tank is swiftly opened. The nitroglycerine then runs away into the drowning-tank, which is a large cooling-cistern placed outside the house.

But if all goes well, the charge, after being separated from the waste acids and well washed in water, flows down the lead pipes into the large filter-house. Here it is drained through two flannels, and then drawn off in rubber buckets and tested by the chemist. Very often it does not pass the test, and has to be rewashed. When the chemist is satisfied with its qualities, it is poured down the pipe running to the settling-house. It stands in conical tanks three or four feet high, and remains in them for a day or more, to allow the water it contains to rise to the surface. Sometimes it is filtered through common salt, which keeps back the water, and thus shortens the time needed for the settling. In powder factories there are many other ingenious devices to diminish the risk of manufacture and obtain a highly purified chemical compound.

After the nitroglycerine has settled, it is ready to be made into dynamite, or compounded into cordite, blasting gelatine or various other explosives. Dynamite is made by mixing the nitroglycerine with infusorial earth, or kieselguhr, which will soak up three times its weight of nitroglycerine; but for blasting purposes a weaker mixture is used. It is taken to the cartridge huts, in each of which there are three girls. One works the press,

which is a cylinder with an ivory piston which pushes the charge into the cartridge. The other two girls wrap up the cartridges, and about every ten minutes a boy comes to the hut and collects the dangerous product.

For mining operations dynamite has largely been supplanted by blasting gelatine and various special powders, usually containing some nitroglycerine, which are more powerful, cheaper, less affected by water, or safer to use in a mine than dynamite. Many of the so-called "safety powders" are very much like dynamite, but have some added substance which reduces the temperature and the length of the flame of a dynamite explosion. Although this cuts down the force of the explosion, it is a desirable change since the flame from a small charge of dynamite has a number of times been known to ignite some fire-damp, or coal-dust, and cause disastrous mine explosions. For some other kinds of blasting work dynamite is also being supplanted by various types of explosives especially designed or adapted for a particular set of conditions. The function of each substance entering into explosives is now so well known by the experts that they can make some explosive mixture which will have almost any desired set of properties.

In modern blasting there is little danger when the men are careful, for all explosives used for industrial purposes are tested in many ways before being put on the market. Usually, industrial explosions in mining and engineering are performed by a shot-firer, working an electric current from a safe shelter. Little is left to chance, for men have learned by experience to control the tremendous force of the gases. This they do by boring shot-holes in the rock or coal they wish to dislodge, the depth and direction of the holes and the amount and the quality of the explosive determining almost exactly the nature and extent of the work performed by the fired charge. Some explosives drive a wedge through a hard material when they go off; others act like a tremendous steam-hammer, and deliver a smashing, crushing blow.

New uses for dynamite; the sword of war beaten into the plowshare of peace

Although dynamite is thus being supplanted, it has found a new field of industry in which it is said to have produced some remarkable results. Dynamite has for a long time been used in agricultural work in preparing new lands for tillage—blowing out stumps and rocks, draining marshes, etc. More recently it has been used extensively in digging the holes for setting out fruit trees and vines. With the present high prices of labor it is found to be actually cheaper to dig holes this way than by hand. But, strange to say, trees planted in dynamited holes are found to thrive much better than those planted in the

an unfertile top soil, and the amount of fertilizer necessary to bring it back into good condition would cost an excessive amount. It has been found, however, that if, instead of merely plowing over about six inches of soil each year, dynamite be used to break up the ground to a depth of five or six feet, many of these old farms may by this means be reclaimed, and by pursuing a proper fertilizing policy, they may be farmed indefinitely. An expenditure of \$10 or \$15 per acre for dynamite will often turn a worn-out farm into one almost as good as new. The weapon of death has indeed proved to be a source of life—furnishing food for thousands of families instead of robbing them of their bravest sons.

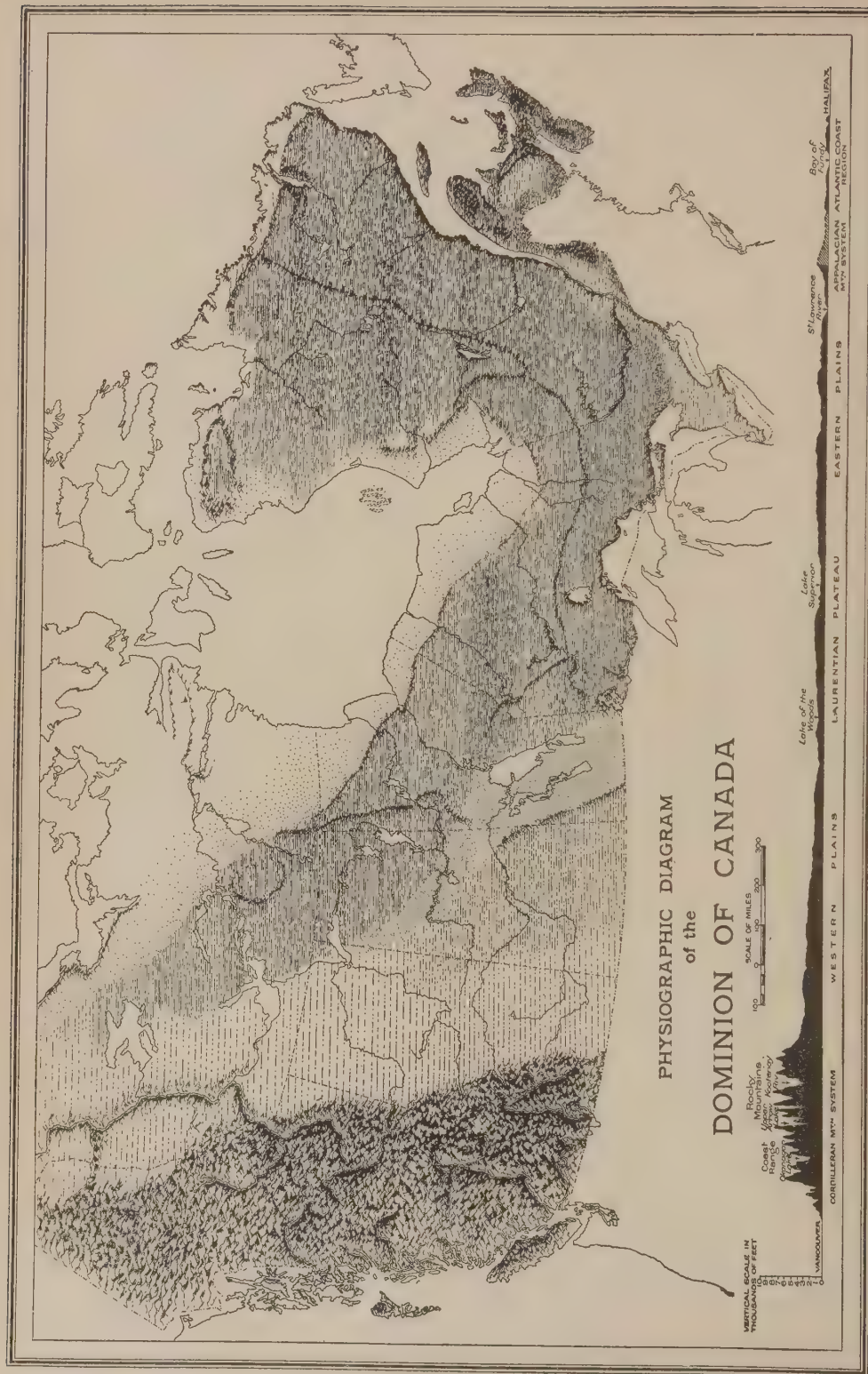


DEEP PLOWING WITH DYNAMITE IN THE WEST—LIGHTING THE FUSE

older way. This may be due in part to a slight fertilizing action of the dynamite, but the more probable causes are the loosening up of the earth for yards around, and the killing off of minute animals and organisms which would otherwise prey upon the young trees and prevent their growth.

The most recent development in agricultural uses for dynamite is for the so-called "deep plowing". As is well known, a considerable part of our rich virgin soil has been exhausted by the farmers taking crop after crop off it without putting any manure back into the impoverished earth. They found it more profitable to move to newly opened tracts when they exhausted the soil in one locality. This selfish policy resulted in the decline of many once prosperous farming communities, for no one cared to run a farm with

Indeed, without explosives, and the hundreds of men who daily risk their lives to make them, the two hundred thousand acres of desert land in America that have recently been irrigated by the Roosevelt Dam would still be a wilderness; the Panama Canal would not have been built; the United States would think of turning to Canada for bread for her vast and still growing population; thousands on thousands of miles of roads and railways now existing would still be waiting to be made; and coal and other important minerals would be less abundant and dearer in cost. In short, the entire industrial development of the world would have been seriously impeded, with the result that the population of the highly civilized races would have either been restricted in growth or compelled to adopt a lower standard of life.



Map specially prepared for THE BOOK OF POPULAR SCIENCE by Natural Resources Intelligence Service, Department of the Interior, Ottawa, Canada.

THE TRADE OF CANADA

The National Resources and Commerce of British North America

A RECORD OF TRULY AMAZING GROWTH

THE Dominion of Canada is the most populous, the wealthiest, and industrially the most advanced of the self-governing dominions of the British Empire. Endowed with magnificent natural resources and inhabited by an energetic people she has an industrial future of extraordinary promise.

One of the most significant facts about Canada is her enormous area of over 3,729,000 square miles, of which over 3,600,000 are land surface. Canada's area is greater than that of the United States, and not much less than that of China. It constitutes nearly a third of the area of the British Empire.

Compared with her enormous area, Canada has at present a relatively small population, although it is rapidly growing. In 1891, it consisted of a little less than 5,000,000 people; at present, there are twice that number. If Canada were as densely settled as Great Britain, her population would be about two billions. If she were as densely populated as the United States, she would have 130,000,000 people. Of course, there are great areas in the extreme north which will, in all probability, never be densely populated. But it is nevertheless true that Canada is one of those parts of the earth — now few in number — which are able to support a greatly increased population without a substantial lowering of the average per capita wealth product. Sir Wilfrid Laurier said that, as the nineteenth century had been the century of the United States, so the twentieth century would be that of Canada. He did not mean that during the twentieth century Canada would overtake

and pass her neighbor in wealth and in population. He meant that during that century the progress of Canada would be even more rapid than that of the United States.

This does not seem altogether impossible, or even improbable, when we survey the extent of Canada's natural resources. In different chapters, we have emphasized the fundamental importance of coal as a foundation of modern industrial progress. Canada has great resources of coal, amounting, it is estimated, to 1,234,000 millions of tons. Moreover, Canada possesses the only important deposits of coal that are closely adjacent to tidewater on either the Atlantic or Pacific coast of either North or South America. The development of the coal fields of Cape Breton (Nova Scotia) is fairly recent, but the annual output is now over 6,000,000 tons a year. These mines not only supply the growing iron and steel industry of Nova Scotia, but are also furnishing coal to the great Canadian railway systems. The coal of Nova Scotia, moreover, is likely to be sent in large quantities to export markets, not only because it is mined, literally, at the water's edge, but also because the harbors of Sydney and Louisburg are nearer the ports of the east coast of South America than are such shipping points for the United States coal as Baltimore and Newport News. It must be remembered, however, that no country has yet been able to develop a large export trade in coal, except as part of a large and well-balanced ocean carrying trade. The full utilization of the Cape Breton coal deposits must wait upon Canada's industrial and commercial progress.

WORKING SOME OF CANADA'S REMARK-



COAL MINE AT LETHBRIDGE, ALBERTA



MAGNESITE MINE, MAGNESITE, QUEBEC



CONSOLIDATED MINING AND SMELTING CO. (copper), TRAIL, B. C.

ABLY VARIED MINERAL RESOURCES



ASBESTOS DUMPS, THEDFORD MINES, QUEBEC



ASBESTOS PIT, THEDFORD MINES, SHOWING TERRACE WORKINGS



SMELTER AND POWER PLANT, GRANBY COPPER MINES, ANYOX, B. C.

In the west, the bituminous coals of British Columbia are likewise near the seaboard, the mines on Vancouver Island in particular being able to load almost directly into steamers. By far the largest part of the Canadian reserves, however, are in the province of Alberta.

CANADA'S GROWING COAL PRODUCTION
(In thousands of tons)

PROVINCE	1911	1915	1927
Nova Scotia . .	6,431.1	7,463.4	7,071.1
New Brunswick .	55.5	127.4	203.7
Saskatchewan .	181.2	240.1	409.9
Alberta	2,894.5	3,360.8	6,929.3
British Columbia .	3,330.7	2,065.6	2,737.0
Yukon Territory .	16.2	9.7	414.0
Total	12,909.2	13,267.0	17,825.0

But Canada does not depend upon coal alone as a source of mechanical energy. Canada is one of the richest countries in the world in water-power as well as in coal. In the great interior provinces of Quebec and Ontario, where coal is lacking, water-power is much the more important source of power. The Dominion Water-Power Branch of the Department of the Interior estimates that the available water-power at ordinary minimum flow will furnish 18,000,000 horse-power, and that over half of this energy is available in the provinces of Ontario and Quebec.

A country of Canada's vast extent with its varied geography and geological structure might be expected to contain a large variety of valuable minerals. Not all of the country has been thoroughly prospected as yet, but it is already certain that Canada is in mineral wealth one of the richest countries of the world. So far as iron ore is concerned, the largest producing deposit in British North America is not in Canada, but is at Belle Isle, Newfoundland. These mines supply the growing iron industry of eastern Canada. Other deposits of ore, however, are found in New Brunswick, Nova Scotia and Ontario.

Canada is one of the few countries of the world which exports copper, although much of Canada's crude copper goes to the

United States for refining. The largest producing deposits are in British Columbia, although the copper content of the copper-nickel ores of the Sudbury region in Ontario are exceedingly important. Monel metal—a useful alloy of nickel and copper—is produced from these ores without separating the two metals.

THE PRODUCTION OF LEAD, ZINC
AND PIG IRON IN CANADA

YEAR	PIG IRON	LEAD	ZINC
	<i>Tons</i>	<i>Pounds</i>	<i>Tons</i>
1910 . .	800,800	32,987,500	—
1915 . .	913,800	46,316,400	12,000
1924 . .	909,000	168,596,000	27,641
1927 . .	794,857	310,183,455	81,802

These deposits at Sudbury are the principal sources of the world's nickel. Nickel-steel is the most important of all alloy steels, and its uses are important in peace as well as in war. Canada produces over three-fourths of the world's nickel, and this proportion is likely to increase in the future. The only other important source of supply is the island of New Caledonia, a French possession in the South Pacific.

CANADA'S OUTPUT OF NICKEL AND
COPPER
(In thousands of pounds)

YEAR	NICKEL	COPPER
1891	4,035.3	9,529.4
1895	3,888.5	7,771.6
1900	7,080.2	18,987.1
1905	18,876.3	48,092.8
1910	37,271.0	55,692.4
1915	68,308.7	100,785.2
1924	69,536.3	104,457.4
1927	66,798.7	140,144.8

In other important ferro-alloys, Canada is fairly well furnished. The chrome (or chromite) ores of Canada are, like those of the United States, of low grade. Cobalt—a mineral which has such diverse uses as in coloring pottery and glass, in insect poisons, and in high-speed tool steels—is obtained as a by-product of the silver ores of the Cobalt district. In fact, only one other region—the Belgian Congo—produces a noteworthy amount of cobalt.

Canada also had large reserves of molybdenum — a ferro-alloy of increasing importance. Titanium, used in steel manufacture, as well as in pigments, in electrodes for arc-lights, and in warfare for making smoke clouds, is also mined in Canada.

Turning to other kinds of minerals, we note that Canada is by far the largest producer of asbestos in the world. Asbestos, or mineral wool, which has important uses in the manufacture of fireproof, heat-retaining, and friction-resisting compounds, finds a large and increasing market. Arsenic is recovered as a by-product in the smelting of the silver-cobalt-nickel-arsenic ores of the Cobalt district. Corundum, an important abrasive, is mined in eastern Ontario. Feldspar, also mined in Ontario, is mostly exported to the United States where it is consumed in the manufacture of pottery. Fluorspar, used as a flux in the manufacture of open-hearth steel, is also mined in Ontario. In the production of gypsum — used in the manufacturing of various plasters and as a fertilizer — Canada is one of the four leading countries, the United States ranking first. In the production of mica, Canada is one of the three countries which together produce 98 per cent of the world's total. Especially notable are the deposits of amber mica near the city of Ottawa.

CANADA'S PRODUCTION OF THE PRECIOUS METALS

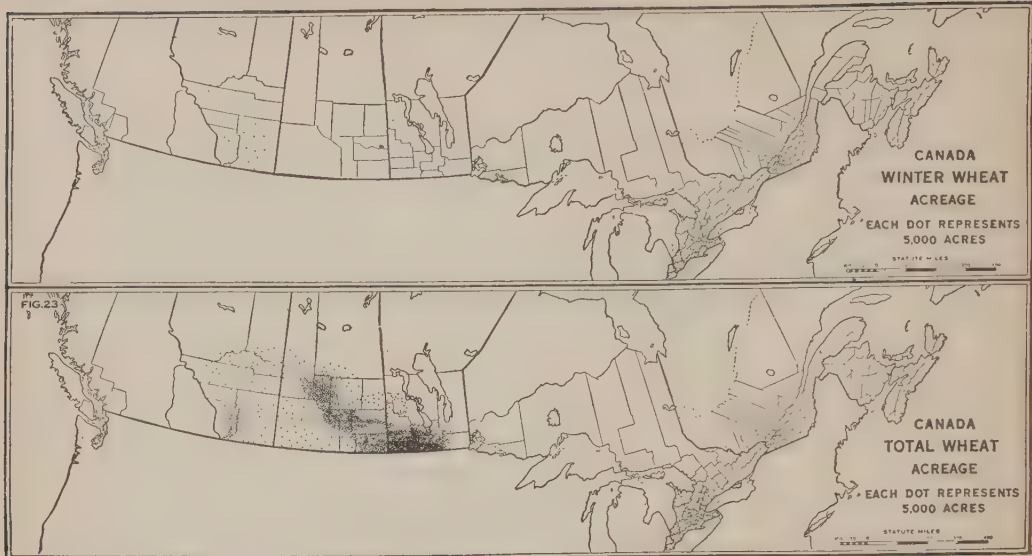
YEAR	SILVER	GOLD	
	Ounces	Ounces	Dollars
1891 . .	414,500	45,018	930,600
1895 . .	1,578,300	100,800	2,083,700
1900 . .	4,468,200	1,350,100	27,908,200
1905 . .	6,000,000	685,000	14,159,200
1910 . .	32,869,300	493,700	10,205,800
1915 . .	26,626,000	918,100	18,977,900
1924 . .	20,363,500	1,525,000	31,522,000
1927 . .	22,371,924	1,844,544	38,130,107

In recent years Canada has been one of the world's great producers of the precious metals. Just before the Great War Canadian production was from a fifth to a sixth as large as that of the United States and about half as large as that of Australasia. More than half of the Canadian gold comes from the Porcupine district in On-

tario, developed in 1912. Gold also comes from British Columbia and the Yukon Territory. The normal output of silver from Canadian mines is at least 25,000,000 ounces per year, and, as contrasted with other countries (including the United States) only a relatively small part of this output is obtained as a by-product of copper or lead mining. The Cobalt district of northern Ontario is the richest silver district in North America, the ore being of exceptionally high grade.

Canada draws its wealth from the sea as well as from the land. It has the most extensive fisheries of any country in the world. On the Atlantic, the lobster, cod, herring, halibut, mackerel, smelt, sardine, oyster and clam are found. On the Pacific coast are salmon, halibut, herring and whale. Salt-water fishing is prosecuted on an extensive scale, both inshore and in the deep sea. The inshore waters of Canada, characterized by numerous harbors and bays, afford easy and safe conditions for boat fishing. Canada's lobster fisheries are the most important found anywhere, and the salmon fisheries of the Pacific coast have a similar rank. In recent years the government has assisted the fishing industry by providing refrigerator cars so as to encourage the consumption of fresh fish by making it possible to transport it without deterioration. Canada's fisheries constitute a practically inexhaustible source of wealth. With the increasing cost of meat and other products of the soil fish is bound to become a more important item of food.

For a long time to come, however, as at present, Canada's most important extractive industry will be neither mining nor fishing, but farming. The development of Canada's grain industry, in particular, has been phenomenal. At the close of the nineteenth century, most of Canada's grain was raised in the province of Ontario, but since that time the western provinces of Manitoba, Saskatchewan, Alberta and British Columbia have been the largest producers. In 1881, Canada produced only 32 million bushels of wheat; in 1915 — admittedly an exceptional year — the wheat crop was nearly 400 million bushels.



From Finch & Baker's "Geography of the World's Agriculture"

VALUE OF PRINCIPAL CANADIAN CROPS
(In millions of dollars)

CROP	FIVE-YEAR AVERAGE 1919-1923	1924	1926 ¹
Wheat . . .	356.8	320.3	459.1
Oats . . .	222.7	203.0	184.1
Corn for husking	14.9	14.2	7.8
Barley . . .	43.2	60.5	37.9
Rye . . .	14.9	14.1	9.3

¹ Figures for 1927 not available

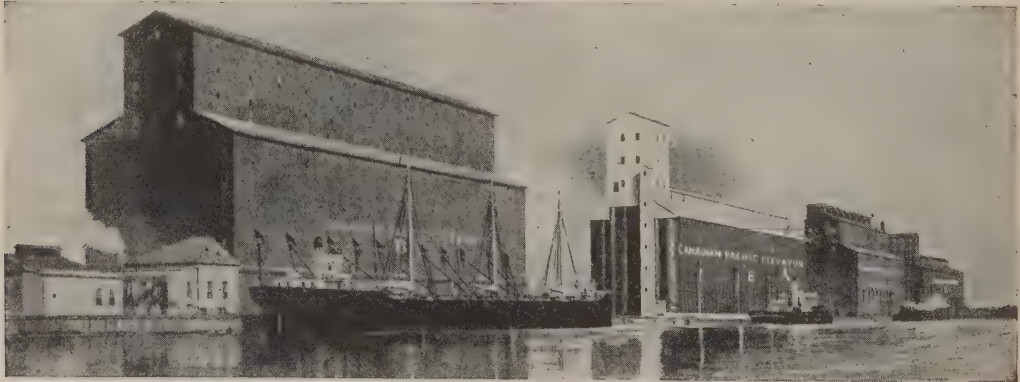
The three prairie provinces of Manitoba, Saskatchewan and Alberta produced in that year 265 million bushels. And it is estimated that less than 10 per cent of the arable land in those provinces has thus far been put under cultivation, although it is reasonable to suppose that the best land is

already under use and that some part of what remains will never prove to be of great value for agriculture.

CANADA'S CROP YIELD
(In millions of bushels)

CROP	1890	1910	1924	1926
Wheat . . .	42.2	132.1	262.0	409.8
Oats . . .	83.4	243.5	411.6	383.4
Corn for husking .	10.7	14.3	11.9	7.8
Barley . . .	17.2	28.8	86.7	99.7
Rye . . .	1.3	1.5	14.2	12.1
Beans . . .	—	—	1.1	1.2
Buckwheat . . .	—	—	11.4	9.9
Mixed grains . . .	—	—	31.9	34.6
Flaxseed . . .	—	—	9.6	5.9
Potatoes . . .	—	—	56.6 ¹	48.7
Peas . . .	—	—	3.2	2.6

¹ millions of cwt.



SHIPPING WHEAT FROM ONE OF THE ENORMOUS GRANARIES ON THE CANADIAN PACIFIC RAILWAY



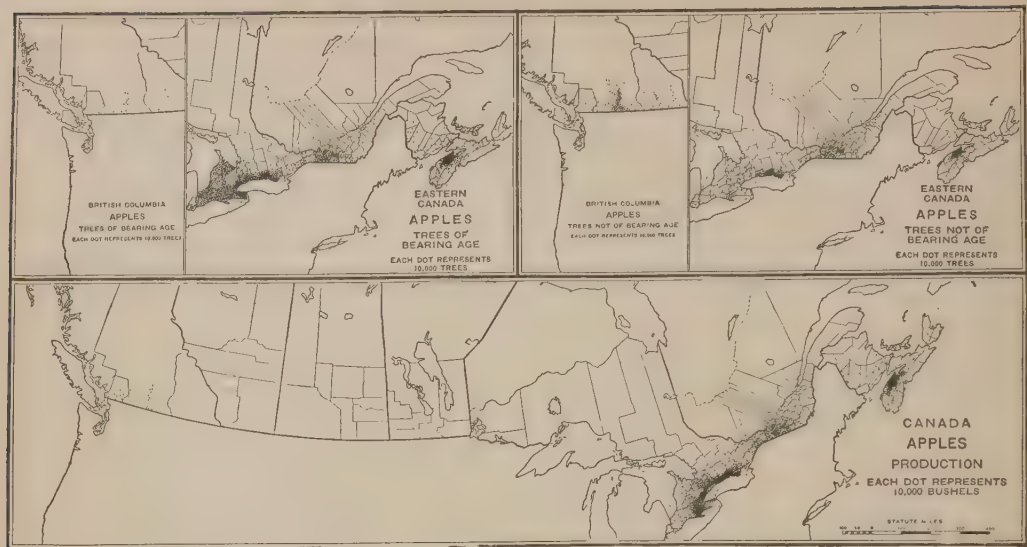
From Finch & Baker's "Geography of the World's Agriculture"

In wheat production Canada now ranks fourth or fifth among the nations of the world, only Russia, the United States, India and possibly France having a larger yield. Oats are in value third among Canadian crops, and, for much of Canada, second. Oats can be grown successfully a little further north than wheat, and this partially accounts for the large oat acreage in the prairie provinces. In Ontario and Quebec, oats, together with the hay crop, are the foundation of the cattle and dairy industries. Barley can be grown successfully in higher latitudes than either wheat or oats. For this reason, it is increasingly important as a Canadian crop. Flax is grown, as in the United States, for its seed, rather than for its fiber. The production of flax fiber of high quality requires an

enormous amount of arduous labor. The relative scarcity and consequent high price of labor makes it unprofitable to raise flax-fiber in the North American continent. But flax is grown for seed in the prairie regions of Canada as it is in the adjoining spring-wheat regions of Minnesota and the Dakotas. It requires a rich soil, and grows well on newly broken prairie sod. The flax is grown mostly in large fields, harvested by machinery, and the seed shipped to the markets where it is pressed for linseed oil. Apples and other fruits are produced on a commercial scale in the Niagara peninsula of Ontario on the north shore of Lake Ontario, and the famous Annapolis Valley of Nova Scotia. Lately there has been a remarkable increase in apple growing in British Columbia.



PLANT OF THE OGILVIE FLOUR MILLS, FORT WILLIAM, ONTARIO



From Finch & Baker's "Geography of the World's Agriculture"

There has also been a remarkable development in raising of pears, peaches, prunes, apricots and other fruits, especially in British Columbia.

But one of Canada's most valuable crops, in fact second in value only to the wheat crop, is hay! In the western provinces, the wild grass of the prairies furnishes an abundant and nutritious crop of hay; farther east, especially in Ontario and Quebec, the cultivated grasses — like timothy and clover — are grown in connection with the important dairy industry which centers in the more thickly settled, non-wheat-growing eastern provinces, although the live stock industry is more important in the west.

Canada's forests have been another source of wealth. In some of the northern latitudes of Canada, it is possible that forests may prove to be the most profitable permanent crop. One distinguishing feature of the exploitation of Canadian forests has been the enormous amount of timber converted into pulp for paper making. The abundance of water-power and the fact that water-power and timber are found in close proximity, have given Canada a remarkable advantage in the manufacture of wood pulp. There is apparently no waste of natural resources in the use of water-power. It is there to be used or not to be used, as may be most wise or profit-

able. It will remain for the use of later generations whether we use it or not. But not so with the forests. The cheapness of water-power and the accessibility of the forests have put a premium upon the too rapid exploitation of Canada's timber. Fortunately, the Canadian government has long appreciated the importance of this problem. In 1909, it established a Commission of Conservation to consider all questions relating to the conservation and better utilization of Canada's natural resources. The committee has studied and reported upon the conservation of coal in Canada, it has studied the sources of the fuels used in Canada's industries, it has published an elaborate report upon Canada's water-powers, and it has made an accurate inventory of the remaining timber resources.

AVAILABLE PULP WOOD AND WATER-POWER OF CANADA

PROVINCE	ESTIMATED PULP WOOD RESOURCES, MILLION CORDS	AVAILABLE WATER-POWER AT ORDINARY MINIMUM FLOW, H. P.
British Columbia .	285	1,931,142
Prairie Provinces .	185	4,259,253
Ontario	200	4,950,300
Quebec	300	6,915,244
New Brunswick .	33	50,406
Nova Scotia . . .	30	20,751

At its suggestion, the government has set aside large areas as forest preserves. A unique report of the commission deals with the subject of fur farming in Canada. Taking a broad view of the meaning of the term "natural resources", the commission has included matters relating to the physical health and strength and conditions of living of the people within the field of its investigations.

We have said above that water-power resources apparently cannot be wasted, that is, they cannot be "used up". But there is a sense in which it may be said that water-power resources can be wasted. They can be devoted to uses which are relatively unimportant, thus throwing a larger burden upon the world's supply of mineral fuels. Dr. C. P. Steinmetz has shown that the maximum hydraulic energy which might be developed in the United States would only equal the present total consumption of mechanical energy therein. That is, if there were no coal and petroleum or other fuels, and if water-power were the only source of energy, the industries of the United States would be faced with the impossibility of obtaining anywhere more energy than they are now using. In only less degree the same considerations hold true of Canada. Although one of the richest countries in the world in both water-power and coal, Canada cannot afford to waste either of them. The use of water-power in the too rapid exploitation of the forest resources of a country may be a real waste of hydraulic energy.

After this brief view of Canada's impressive natural resources, we may profitably turn to the statistics of her foreign trade. The status of a country's foreign trade better than almost anything else gives a clue to the nature and degree of advancement of her industries.

The first thing to be noted is the extraordinary expansion of Canada's exports from less than \$100,000,000 a year before 1892, to \$300,000,000 or \$400,000,000 annually in the years just before the war, and to between a billion and a billion and a half in the years immediately following. Of course, some of the increase in Canada's trade in the years immediately following the war is only apparent, being merely a reflection of the diminished purchasing power of the dollar, but, making all proper allowance for this fact, it remains true that Canada's foreign commerce has been increasing with marvelous rapidity. The figures may seem relatively small as compared with the very much larger figures we have given for the United States in the preceding chapter, but a careful comparison is not at all to the disadvantage of Canada. In fact, on a per capita basis, her exports are very much larger than those of the United States. When one takes into account the fact that the annual per capita wealth product of the United States is somewhat larger than that of Canada, it will appear that Canada's export trade bulks much larger, compared with the total volume of her domestic trade, than does the export trade of the United States. Canada, it will be seen, is thus distinctly more a "trading nation" than is the United States. This does not mean that her commercial progress has been more rapid than that of her southern neighbor. It merely means that Canada's industries are more specialized, and that Canada has found that state of affairs more profitable than a higher degree of economic self-sufficiency would have been. The United States produces a relatively larger proportion of what it consumes; Canada relies more largely upon an interchange of commodities with other nations.



MILLS OF THE SPANISH RIVER PULP AND PAPER CO. AT SAULT STE. MARIE, ONTARIO

CANADA'S TRADE: 1872-1928

FISCAL YEARS	IMPORTS	EXPORTS
	Dollars	Dollars
1872 . . .	104,955,367	78,629,265
1873 . . .	124,509,129	85,943,935
1874 . . .	123,180,887	87,356,093
1875 . . .	117,408,568	76,847,142
1876 . . .	92,513,107	79,726,398
1877 . . .	94,126,394	75,141,654
1878 . . .	90,395,851	79,154,678
1879 . . .	78,702,519	70,786,669
1880 . . .	69,900,542	86,139,703
1881 . . .	90,488,329	97,319,818
1882 . . .	111,145,184	101,766,110
1883 . . .	121,861,496	97,454,204
1884 . . .	105,972,978	89,222,204
1885 . . .	99,755,775	87,211,381
1886 . . .	95,992,137	85,194,783
1887 . . .	105,107,210	89,510,242
1888 . . .	100,671,628	90,185,466
1889 . . .	109,098,196	87,210,911
1890 . . .	111,682,573	94,309,367
1891 . . .	111,533,954	97,470,369
1892 . . .	115,160,413	112,154,257
1893 . . .	115,170,830	114,430,654
1894 . . .	109,070,911	115,685,569
1895 . . .	100,675,891	109,313,484
1896 . . .	105,361,161	116,314,543
1897 . . .	106,617,827	134,457,703
1898 . . .	126,307,162	159,529,545
1899 . . .	149,346,459	154,880,880
1900 . . .	172,506,878	183,237,555
1901 . . .	177,700,694	194,509,143
1902 . . .	196,480,190	209,970,864
1903 . . .	224,813,719	225,229,761
1904 . . .	243,590,019	211,055,678
1905 . . .	251,617,119	201,472,061
1906 . . .	283,282,204	246,657,802
1907 (9 mos.)	249,737,874	192,087,233
1908 . . .	351,879,955	263,368,952
1909 . . .	288,217,515	259,922,366
1910 . . .	369,815,427	298,763,993
1911 . . .	451,745,108	290,000,210
1912 . . .	521,448,309	307,716,151
1913 . . .	670,089,066	377,068,355
1914 . . .	618,457,144	455,437,224
1915 . . .	455,446,312	461,442,509
1916 . . .	507,817,159	779,300,070
1917 . . .	845,330,903	1,179,211,100
1918 . . .	962,543,746	1,586,169,792
1919 . . .	916,429,335	1,268,765,285
1920 . . .	1,064,516,169	1,286,658,709
1921 . . .	1,240,158,882	1,210,428,119
1922 . . .	747,804,332	753,927,009
1923 . . .	802,579,244	945,295,837
1924 . . .	893,366,867	1,058,553,297
1927 . . .	1,030,892,503	1,267,573,142
1928 . . .	1,108,918,808	1,228,207,606

For the nature of Canada's specialization, see table at the top of the next page.

Canada's own splendid supplies of coal being near either the Atlantic or Pacific coasts, her interior provinces have found it profitable to import large amounts of coal from the United States. Manufactured goods, such as textiles, iron and steel products, bulk larger in Canadian imports than in her exports. Among the exports, farm products constitute, as they have in the past, the most important single item. But the extraordinary importance of one other class of goods—wood, wood products and paper—should be noted. It will be seen that by far the largest part of this class of exports goes to the United States. Possibly a fourth of this trade is in saw-mill and planing-mill products—lumber of different sorts. Most of the rest is made up of printing paper, pulp-wood, and wood pulp. Canada's forests have gone into the making of American newspapers. One wishes that one could be sure that in every case the sacrifice of the forests has been justified by the value of the ultimate printed product! It is not at all unlikely that we are approaching the time when the increasing scarcity of wood pulp and of the other vegetable fibers of which paper may be made will force a reduction in the number, or at least in the size, of our daily papers. This enforced economy may possibly prove to be not an unmixed evil. Surely there is in the making of our newspapers, as in the making of other parts of the complicated apparatus of modern life, room for more emphasis on quality rather than quantity.

If the reader will take the trouble to compare the total volume of Canada's exports with the total volume of her imports in successive years, he will note that in almost every year between 1872 and 1915, Canada imported more than she exported. In the aggregate, before the Great War, Canada's imports exceeded her exports by many hundreds of millions of dollars. Is this an exception to the general economic law explained in an earlier chapter that a country's imports and exports must in the long run tend to equal each other? The exception is only apparent, for statistics of commodity exports and imports, of "visible" trade, as it is

MAIN CLASSES OF CANADIAN EXPORTS AND IMPORTS IN THE FISCAL YEARS
ENDING MARCH 31, 1914 AND 1927

CLASSES	TOTAL TRADE		TRADE WITH UNITED KINGDOM		TRADE WITH UNITED STATES	
	1914	1927	1914	1927	1914	1927
<i>Imports</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>
Vegetable products . . .	97,627,371	213,098,121	16,202,907	38,254,029	44,118,714	97,104,543
Animal products . . .	41,092,915	53,214,135	5,737,729	5,407,837	23,295,875	35,439,469
Fibers and Textile products	109,153,861	183,583,931	60,577,216	72,752,164	32,535,525	66,925,517
Wood, wood products and paper	37,397,394	47,962,298	3,704,340	3,918,098	31,723,052	41,122,392
Iron and its products . . .	143,864,735	220,429,485	17,262,813	15,008,951	121,342,038	206,655,021
Non-ferrous metal products	35,664,771	52,747,842	4,785,570	5,642,570	27,818,942	42,872,108
Non-metallic mineral products	85,157,392	156,784,707	6,281,813	9,253,721	74,060,769	131,984,446
Chemicals and allied products	17,104,393	31,844,715	4,293,412	4,906,256	9,583,462	20,630,534
All other commodities . . .	52,131,166	62,227,271	13,224,666	8,797,426	31,823,761	44,973,689
Total imports . . .	619,193,998	1,030,892,505	132,070,406	163,941,052	396,302,138	687,707,719
<i>Exports</i>						
Vegetable products . . .	201,446,644	574,994,162	146,854,812	330,073,479	34,095,266	59,953,683
Animal products . . .	76,591,015	167,291,589	35,419,016	67,819,473	32,320,872	75,320,135
Fibers and textile products	1,933,513	7,665,563	234,364	860,030	1,201,699	3,451,081
Wood, wood products and paper	63,201,624	284,120,267	12,805,898	15,835,904	45,186,230	242,019,601
Iron and its products . . .	15,483,491	74,284,824	1,430,560	8,129,365	2,044,031	10,680,762
Non ferrous metal products	53,304,267	80,639,197	16,561,574	14,174,289	34,341,591	39,007,020
Non-metallic mineral products	9,263,643	28,509,838	434,816	2,324,119	7,155,999	17,251,325
Chemical and allied products	4,633,044	16,574,753	496,469	3,567,256	3,051,518	8,092,371
All other commodities . . .	5,731,198	18,077,313	1,016,460	4,092,186	3,975,619	10,643,561
Total exports . . .	431,588,439	1,252,157,506	215,253,969	446,876,101	163,372,825	466,419,539

called, take no account of a number of "invisible" items. In the case of Canada, the most important invisible item has been the continuous flow of foreign capital, and especially of British capital, attracted by the opportunities created by Canada's unexploited resources. Mr. F. W. Field, editor of the *Monetary Times* of Toronto, has estimated that British investors sent more than \$600,000,000 to Canada in the five years preceding 1910, and that United States investments in Canada during the same period were approximately \$280,000,000. Altogether, foreign investments in Canada during those five years amounted, Mr. Field says, to nearly a billion dollars. These foreign investments, it is clear, must enter into the general balance of trade. Canada's excess of visible imports over visible exports created, as it were, an international debt, with Canada as debtor and other countries as creditors. But the credi-

tors, instead of insisting upon Canada's paying them in money of their own countries, preferred to take payment in Canadian funds and to invest these payments in Canada. In actual fact, of course, Canada's creditors on account of her adverse trade balance were rarely the same persons who invested capital on such a large scale in Canadian enterprises. But so far as the operations of international trade and foreign exchange are concerned, the account just given, in its general outlines, is substantially correct. Another conclusion that may be drawn from the same facts is that, if it had not been for the large investments of foreign capital within Canada, Canada's visible exports and imports would have been more nearly equal.

Soon after the beginning of the Great War, with Great Britain and other European countries unable to make further investments in Canada, and, in fact, with the tables turned so that Canada was giv-

ing financial, as well as military, support to Great Britain, we find an immediate reversal in the current of trade. Canada's exports, in great demand for the supplies of the armies and civilian populations of Europe, came to exceed her imports, a condition which persisted during the years of reconstruction following the war.

WHERE CANADA TRADES

PRE-WAR AND POST-WAR CANADIAN EXPORTS
AND IMPORTS CLASSIFIED BY COUNTRY

(The figures are in millions of dollars and are for fiscal years ending March 31, 1914 and 1927.)

COUNTRY	EXPORTS		IMPORTS	
	1914	1927	1914	1927
<i>British Empire</i>				
United Kingdom .	215.3	446.9	132.1	163.9
British East Indies	.6	10.0	7.2	10.5
British Guiana	.6	2.4	3.2	4.6
British West Indies	4.5	7.6	4.3	13.8
Hong Kong	1.9	1.5	1.0	1.4
Newfoundland	4.5	11.2	1.8	1.8
Australasia	6.8	21.4	4.1	10.3
South Africa	3.8	8.4	0.5	1.0
New Zealand		13.5		4.6
Irish Free State		6.0		
Egypt		1.5		
Other British Countries	.6	7.2	.3	1.5
Total — British Empire	238.6	537.6	154.5	213.4
Argentina	2.1	13.1	2.6	5.7
Belgium	4.3	21.3	4.5	9.7
Brazil	.8	7.3	1.2	2.0
Chili	.1	1.5	.8	
China	.5	13.5	.9	5.0
Cuba	1.8	6.8	4.0	8.1
Denmark	.6	5.7	.1	
Dutch East Indies		3.7	1.0	
France	3.6	15.2	14.3	24.0
Germany	4.0	34.4	14.6	15.0
Greece		6.0	.4	
Italy	.5	22.8	2.1	3.4
Japan	1.6	29.9	2.6	11.2
Mexico	.1	2.8	1.5	2.4
Netherlands	4.0	26.4	3.0	7.7
Norway	0.9	5.0	.5	.9
Peru		1.4	.7	5.9
Russia	1.4	2.4	.5	
San Domingo	.1		2.9	6.0
Sweden	.2	3.4	.6	1.6
Switzerland			4.3	9.5
United States	163.4	466.4	396.3	687.7
Other Countries	3.5	21.8	5.3	11.7
Grand Total	432.1	1248.4	619.2	1030.9

Turning to the tables showing Canadian trade with different countries, we note at once the overwhelming importance of her trade with Great Britain and the United

States. Thus, in 1914, 50 per cent of her exports went to the United Kingdom, and 38 per cent to the United States, leaving only 12 per cent for all other countries taken together. In 1927, 36 per cent of her exports went to the United Kingdom; 37.7 per cent to the United States; and 27 per cent to other countries, a considerable increase in this direction, mainly at the expense of Great Britain. Of her imports in 1914, Canada drew 21 per cent from the United Kingdom, and 64 per cent, or nearly two-thirds, from the United States, leaving 15 per cent from other countries. In 1927, only 16 per cent came from Great Britain, 67 per cent from the United States, leaving 17 per cent from other countries, a decrease of 5 per cent from Great Britain, an increase of 3 per cent from the United States and an increase of 2 per cent from other countries. This change is in part a reflection of an abnormal situation. Nevertheless, Canada's trade across the border is likely in the long run to constitute her most important and most profitable commerce. In its general nature, if protective tariffs did not intervene, it would be substantially like the domestic trade which is carried on between different sections of either the United States or Canada. This trade is so natural, so inevitable, and so profitable to both countries concerned, that, whatever may be said of the merits of the protective tariff in general, its particular application in this case seems hard to justify.

Canada, as a loyal component of the British Empire, grants preferential, that is to say, lower, tariff duties to England and to certain other parts of the Empire which have given corresponding concessions to Canada. Opinion with respect to the effect of the preferential tariff upon Canadian as well as British welfare is divided. It is clear that it has had some effect in increasing Great Britain's share in Canadian trade, but it is also clear that this effect has been relatively slight.

Among the other countries with which Canada's trade is large and growing, the British West Indies, Australasia and various countries of continental Europe, stand out prominently. In general, the impression which the Canadian trade statistics give

is that of an important and growing foreign commerce somewhat highly specialized, both with respect to the character of the trade and the countries traded with. It is, however, a trade which is suited to the present needs and economic status of Canada. It will unquestionably become more diversified as Canada, like the United States, becomes more densely settled and finds a larger development of manufacturing more profitable. Canada's eco-

nomie present is one in which agriculture, forestry and fisheries predominate. Its future may very well be one in which agriculture, although gaining in absolute importance, loses somewhat as compared with other industries, in which the exploitation of Canada's forests will necessarily play a smaller part, and in which Canada's great stores of mechanical energy in the form of coal and water-power will be the basis of a new manufacturing era.

SEVENTY LEADING COMMODITIES EXPORTED FROM CANADA, BY VALUES, 1927

COMMODITY	VALUE	COMMODITY	VALUE
	<i>Dollars</i>		<i>Dollars</i>
Wheat	353,094,940	Films	5,104,042
Printing paper	116,993,256	Machinery	4,755,925
Wheat flour	68,720,334	Logs (wood)	4,747,431
Planks and boards	59,795,171	Apples, green	4,670,091
Wood pulp	49,887,739	Automobile parts	4,665,369
Fish	34,498,702	Fertilizers	4,613,059
Automobiles	31,751,252	Milk, condensed	4,537,369
Meats	29,408,705	Clover seed	3,760,936
Barley	25,875,024	Soda and soda compounds	3,601,048
Cheese	24,956,179	Hardware and cutlery	3,380,762
Raw furs	20,285,005	Butter	3,351,589
Whiskey	18,712,574	Ferro-manganese and ferro-silicon	3,351,423
Rubber tires	18,564,229	Poles (wood)	3,323,415
Farm implements	17,412,947	Hay	3,246,170
Pulp wood	15,400,343	Paper board	2,733,747
Sugar, refined	15,116,239	Abrasives, artificial, crude	2,677,657
Copper ore and blister	13,854,057	Square timber	2,660,282
Lead	13,464,483	Acids	2,639,601
Silver ore and bullion	12,976,334	Raw tobacco	2,569,300
Nickel	12,921,190	Rolling mill products	2,331,169
Cattle	11,579,057	Tubes and pipes	2,064,401
Asbestos, raw	10,614,694	Wrapping paper	2,051,390
Potatoes	9,717,425	Bran and shorts	2,017,558
Laths (wood)	8,997,095	Cereal foods	1,895,259
Milk and cream, fresh	8,740,979	Electric apparatus	1,698,411
Oats	8,598,755	Musical instruments	1,647,925
Zinc	8,444,560	Binder twine	1,626,399
Shingles (wood)	8,415,970	Oatmeal	1,624,029
Leather, unmanufactured	8,364,632	Raw wool	1,538,660
Coal	7,187,000	Aluminium manufactures	1,150,025
Raw hides	7,058,766	Crude petroleum	1,135,422
Settlers' effects	6,994,877	Fish oils	1,058,126
Raw gold	6,854,342		
Rubber boots and shoes	6,374,621	Total value of above commodities	1,186,183,497
Rye	6,050,140	Total value of exports (Canadian)	1,252,157,506
Malt liquors	5,554,092	Percentage represented by above commodities	94.8
Flaxseed	5,371,830		
Aluminium in bars	5,347,969		

HOW THE ANCIENT ROMANS SUPPLIED THEIR CITIES WITH WATER

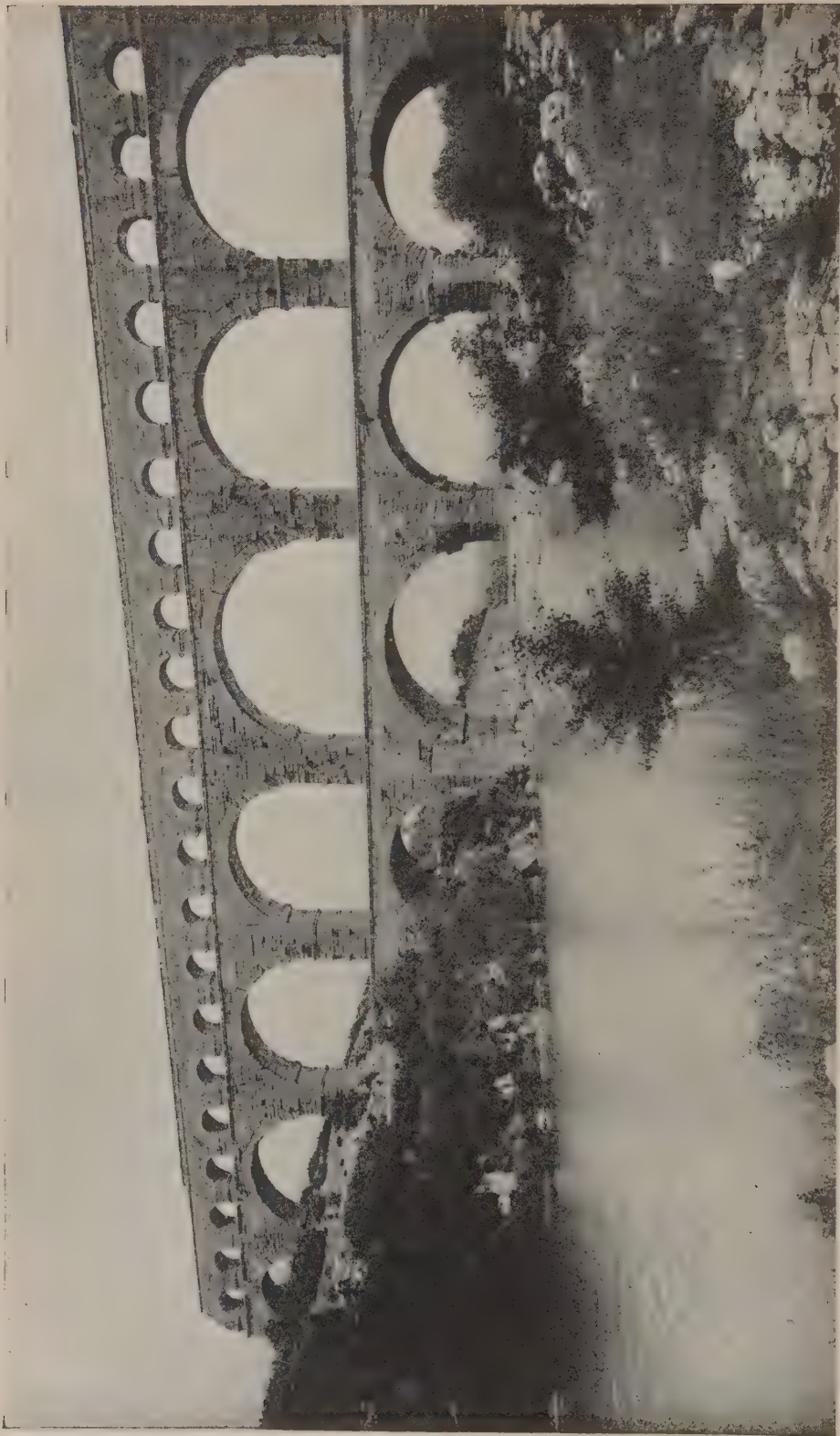


Photo N. D.

THE PONT DU GARD, ROMAN AQUEDUCT BUILT ABOUT 19 B.C. AND STILL STANDING IN NÎMES, SOUTHERN FRANCE

The length along the top is 855 feet, and the central arch has a span of 80 feet.

A CITY'S WATER SUPPLY

How Our Great Cities Are Supplied with
One of Nature's Most Precious Gifts

THE MODERN SOLUTION OF AN ANCIENT PROBLEM

WATER, more than anything else, fixes the abode of man. That was so even when he thought chiefly about defense in making his home refuge. The camp or fort must have water — preferably a spring that could not be diverted. It is so today. When men pitch a military camp, though but temporarily, their first considerations are those of the primitive man — dryness underfoot and water near by.

Villages were built on brooks, or in the region of wells, and towns grew up on rivers, first to secure water, and then easy transit, and sometimes power. In land where the population is nomadic, or migratory, the variations in water, in the rainfall or the wells, govern the movements of the community. Indeed, man must follow water, or he must arrange that the water shall follow him. During the early stages of his civilization, when the conditions of his life were simple, he went to the water; now, with enormous labor, far-projected foresight, vast capital expense, and marvelous engineering skill, he gathers the rain from a hundred hills beyond the horizon, and distributes it inside the houses of a million people, so that a little child may turn a tap and drink. This is the story of that gathering and dispersal of the waters.

Looked at in detail, as it affects an individual man or a family, the question of amount in water-supply does not appear serious. A great engineer has pointed out that if it were possible to preserve from evaporation as much of the annual rainfall of London as could be caught by an up-turned umbrella of full size, the year's accumulation would be enough to last one man for drinking purposes for a year.

So, on the slated roof of a cottage giving an expanse of 500 square feet there would fall in Massachusetts, at the low rate of 40 inches per depth per year, enough rain to provide the family with 30 gallons of water daily, an amount that probably is not exceeded in ordinary cottage life.

Though it may seem easy to collect these and larger quantities of water under rural conditions, the problem becomes greatly intensified when water must be made instantly available to huge and dense populations in cities for industrial and civic as well as domestic purposes.

For instance, the water consumption of New York City, with a population of 5,839,738, is about 732,000,000 gallons from all sources per day. In London, with a population of about seven and a half millions, it is only 225,000,000 gallons, yet even in order to supply that demand it is calculated that a stream is needed running day and night, at the rate of two miles an hour, 30 feet wide and 4 feet deep.

In ancient times the problem of water-supply for the great cities was greater because engineering power was less. As one approaches Rome the first signs of its ancient magnificence are observed in the gaunt ruins of mighty aqueducts which here and there bestride the drear Campagna. Nine aqueducts were in use in Rome in the year A.D. 97, and two others were added later. They brought water into the city from distances varying between eleven and sixty-two miles. The greater part of these conduits was underground, but they emerged as they neared the city, and were carried on arches, as illustrated in the impressive ruins of the Aqua Claudia.

INCLUDING MANUFACTURING, ENGINEERING, TRANSIT AND EXCAVATION

Our water system of today in use two thousand years ago

These aqueducts were chiefly constructed of bricks, stone, and concrete, though lead, bronze, and wooden pipes were used for the final distribution of the water to the houses and baths. The engineering was such as to allow of the use of gravitation as the power throughout, though the principle of the siphon was understood, and had been adopted in earlier ages by the Phœnicians. An unusual proportion of the Roman water-supply would be used for their baths, the bath being a sort of central institution in the social life of the city — club, library, restaurant, and place of amusement.

The treatment of the water was curiously similar to ours of today; that is, the supply was sent forward to service reservoirs, and was only finally distributed after it had passed through settling and filtering tanks. The remains of Roman-raised watercourses can be found in various parts of the Empire, the three-tier aqueduct at Nîmes, 160 feet high, known as the Pont du Gard, and the two-tier aqueduct of Segovia in Spain, being the most characteristic examples. The Roman treatment of the subject was typical of the great cities of antiquity; and Athens and Jerusalem still use a remnant of supplies that were probably engineered 2000 years ago.

The unending race between the population of cities and their water-supply

Of all the departments into which public work divides naturally, none perhaps requires so much forethought and protracted expenditure before a remunerative return is made as the provision of a plentiful supply of good water for a great city. The increasing demand for water in a rapidly developing town is extraordinarily swift and inexorable, and there are cities like Chicago that have been forced to enlarge their supply lines many times. No urban community is keeping pace with its public duties if it has not secured a water-supply sufficient to meet the growth of the next twenty years.

One reason for far-reaching preparation is the peculiar variability of rainfall and a consequent liability to destructive drought. On a gathering ground that is quite favorably situated the supply may sink in a dry year to only about 60 per cent of the average supply of fifty years. Another reason is the impossibility of quickening the command of water to meet emergencies — the enterprise of securing a constant volume of water is comparable to a slow siege, deliberately planned, carefully laid out, skilfully timed.

The enormous cost of waterworks makes it imperative that successive additions should only be completed and be brought into use as they are needed, for a city can as little afford to have too much artificially gathered water as to have too little, since it pays for all it gathers, whether it uses it, leaves it, or wastes it. Hence water-supply is a question demanding far-reaching thought; and the operations it entails illustrate the true use of capital perhaps more perfectly than any other municipal or national enterprise. Millions of money have often been sunk, in foresight and faith, before a cent has been received in return.

The taint of the shallow well and the earth-filtered purity of the deep well

The three usual methods of procuring water are by the use of springs or the sinking of wells; by an intake from rivers; or by conveying from afar the waters of lakes, or damming up valleys and so forming artificial lakes or reservoirs in hilly or mountainous districts. Some cities still use the first of these methods, as at Memphis, Tenn., and Peoria, Ill., but, as cities grow, wells are apt to be discarded in favor of rivers or lakes that will furnish less limited amounts of water.

Spring or well water is the ordinary village supply, and is used in a supplementary way in many large towns where there is a regular piped supply of assured purity. One of the duties of the local health authorities in such towns is to search out the surface wells, that are liable to pollution even if not already polluted, and to put them out of use.

A PURE WATER SUPPLY GUSHING FROM ARTESIAN WELLS



Flowing artesian well at San Antonio, Texas. The water is conducted to the surface through about 700 feet of 10-inch pipe and the quantity is sufficient to create a permanent creek of considerable size.

Artesian well, 516 feet deep, at Saint Augustine, Florida. It discharges a million gallons a day.

Why the water from deep wells has to be stored under cover

There are of course, on the other hand, many cities, particularly along the Atlantic Coast and throughout the Middle West, where ample quantities of pure water are obtained from deep wells. Thus at Rockford, Ill., about three million gallons a day are taken from wells from 500 to 1500 feet deep. At Memphis, Tenn., 90 wells, 500 feet deep, are connected with a large tunnel nearly a mile long from which the water is lifted by powerful pumps into the distributing system.

Water pumped from deep wells has to be stored in covered reservoirs, as under the light it scums over with a green vegetation, whereas the surface waters gathered from mountains by gravitation into lakes and reservoirs remain free from such growths.

Wells that leap to the surface and are never exhausted

The supreme instance of service from wells is Brooklyn, which receives nearly thirty million gallons per day, or almost one-sixth of its whole supply, from its wells which penetrate into the water-bearing sands that form so large a part of the south side of Long Island. These are true surface wells drawing on the vast underground body of water that has been collected directly from the rainfall.

Artesian wells, so called from Artois, the old province in northern France known as Artesium, where such wells have long been used, are the upspring of water confined below an impermeable stratum, which, being bored through, gives the water its release, and it rises to find its natural level. The city of Jacksonville, Florida, is supplied with six million gallons and San Antonio, Texas, with twelve million gallons daily from wells of this character. Sometimes the water from such wells rises in a fountain above the ground level and so sometimes it does not reach the surface, but the cost of pumping is always reduced when compared with such deep well pumping as at Rockford, where the water level is a hundred feet below ground.

The likelihood of rivers becoming contaminated below their upper reaches is obvious, but there is an equal certainty that their waters can be purified for drinking. The drinking water of many of the largest cities of this country comes from rivers, and because of the skill and care used in treating the water before it goes to the consumers, the effect of the contamination is eliminated. Pittsburgh is supplied from the Allegheny River; Cincinnati and Louisville from the Ohio; Philadelphia from the Delaware and the Schuylkill rivers; and New Orleans from the Mississippi.

The need of a National Water Board to divide the nation's water-wealth

Waters for human consumption may be divided into those which are impure originally, but are cleansed and made innocuous, and those which have never been impure. Most of the river waters belong in some degree to the former class. First by storage and settlement such waters lose their bacteria largely, and then are made safe for use by filtration. Still, the ideal water-supply is that which has never been impure, and it usually has the further advantage that, descending from hilly regions, it can be stored at a great height in service reservoirs — at such a height, indeed, that, without pumping, the water will flow of itself to the top stories of the highest buildings in a city of varying altitudes.

Undoubtedly a time will come when the great cities of our country will need the use of all the untainted lofty gathering grounds of water, and will be ready to compete for them with a vigorous expenditure of borrowed money. Then authority will have to be called on to make a division. At present there is a sort of promiscuous seizure, regulated only by the municipal purse and some very inadequate laws. What will be needed is a National Water Board apportioning the national water-supplies throughout the country.

Some approach towards this condition of things has already been made under the pressure of circumstances in various states.

The custom of dividing hill-waters among the people towards whom they flow

In New York State in 1905 the demands for water on the part of New York City had become so great, over 300 million gallons a day, that neighboring communities became alarmed lest all the available water in the southeastern part of the state would be appropriated. Already in 1904 Dutchess County had secured legislation prohibiting any outside locality acquiring water rights in that county, and the mere suggestion that the needed water be found in Connecticut roused such protest as to show plainly that citizens of the latter state did not intend to supply drinking water to those in the former, if any law could be found to prevent. The State Water Supply Commission, since absorbed by the State Public Service Commission, was created in 1905, to adjudicate the claims of various contending interests in the same waters. Before that, any city or water company, once granted a franchise, could acquire by purchase or condemnation any water, with any accompanying lands, without any regard for either present or future necessities for water that the people in that vicinity might have. The first claimant took the water and later would-be users went without.

The city of Boston has displayed great foresight by forming all of its suburbs with itself into a great metropolitan water district and then tapping rivers large enough so that all of its people will be supplied.

This plan of coöperation and friendly division is bound to be carried out with frequency in the future, and the sooner some national preservation and apportionment of the water-wealth of the hills is made the better. It can only be done by wide areas which contain considerable urban populations, and villages requiring additional outside supply taking joint action and dividing pro rata the cost of storage and main pipe-line distribution, while each area of water-users pays for its own local distribution. Those who wait longest will fare worst.

At present there is no scheme of national conservation, but legislative customs are being established for the dividing up of the hill-waters among the people to whom they would naturally flow. The legislative and legal views of water-gathering have been almost entirely confined hitherto to regulating the amount of water that can be taken from a stream for irrigation, the relative rights of upstream and of downstream riparian owners, and the value of priority claims. But not all the water in a stream may be taken out.

The basin of water that gains more as more is taken

The amount left for the use of those who dwell on the banks of the stream, mill-owners, manufacturers, and so on, varies according to the industries of the district, one-third of the total flow being the maximum compensation allowance. In any case the regulation of the water sent down the stream, its restriction, if need be, to hours when it can be properly utilized, and the attention given to the releasing of the flow of water from the saturated upper grounds into the beds of the streams that feed the reservoirs, tend to improve and equalize the ordinary supply, so that, beyond the storage of pure water for distant towns, there is an advantage to the people who dwell by the banks of the stream. The flow is improved for practical purposes, not injured, by the works which retain water. A judicious storage gives a more even supply, and less waste. This ought to be so, for from twenty to twenty-five per cent of the outlay on waterworks is spent in providing compensation water.

How the water-wealth of a mountain valley is calculated

When a stretch of lofty and lonely mountainous land is coveted as a gathering ground for the water-supplies of a city the first question to be settled is how much water does it discharge normally into the streams that will fill the projected reservoirs. The calculation is far from simple. A single rain-gauge's record cannot be relied on, for local position has a marked effect on the registration of a rainfall.

Three stages of city water supply: storage, conveyance, distribution

An average should be taken of a number of gauges. Then the rain that falls is not an index, necessarily, to the amount of water that finds its way into the streams which feed the dams. The character of the soil must be considered. From some soils water flows off quickly and is lost in floods. Other soils become saturated like a sponge, and slowly give up their watery stores. Evaporation is swifter and more constant in one place than another. After long drought the earth is only slowly charged with moisture by percolation, though its thirst may be keen. The water-producing power of any locality varies enormously from time to time. Thus, a huge spongy mountain will discharge into the stream at its foot, at one part of the year, in a given period, 1500 times as much water as it will discharge during an equal period at another season. From this immensely variable output an average has to be obtained before the water-wealth awaiting the reservoir-maker can be calculated.

The enterprise of providing a gravitation water-supply to a city divides itself into three stages — the storage, the conveyance, and the distribution of the water. Usually the storage is artificial, but in a few cases it is natural with artificial additions, as in the use of Hemlock Lake by Rochester, N. Y., or Sebago Lake by Portland, Maine.

How millions of tons of water are held up safely in the hills

In some cases, as at Skaneateles Lake, which supplies Syracuse, N. Y., the necessary storage had to be gained by building a dam at the outlet of the lake to prevent the spring flood from escaping. The mill owners on the outlet — a score or so of them — had to be bought up, and then the stored water could be gradually paid out as the city needed it. In other cases, as at Sebago Lake, the natural storage is ample. Perhaps the most extensive and comprehensive works ever built are those at Los Angeles, Cal., completed in 1916 at a cost of 25 million dollars.

The water for this city of considerably over half a million comes from a glacier-fed river high up on the Sierra Nevada Mountains 223 miles away. The work involved 60 miles of open canal, 119 miles of concrete conduit and steel pipes, and 43 miles of tunnel. It was a tremendous undertaking for a single city, but now, happily completed, solves the water problem for Los Angeles for all time.

Perhaps the chief interest in water-storage enterprise is excited when huge masses of masonry have to be sunk deep into the earth and raised high above it to block valleys and bank in their waters, thus forming artificial lakes or a succession of reservoirs. Dams of this kind are either made with earthen embankments having a central core of puddled clay, or they are made of masonry. Sometimes in old dams earthwork was backed by timber, and there are instances of steel being used. Whether the embankment be of earth or of masonry, a deep trench down to a firm bottom is cut, and is puddled with clay so as to make sure that there will be no percolation through the underlying strata. The bank is then usually built up with concrete in which blocks of stone are thickly embedded, and the wall above water is faced with stone.

The strength of the dam is made commensurate with the anticipated pressure of the water. Thus, the dam of the Vyrnwy Lake, in Wales, supplying Liverpool, holds 12,000 million gallons behind a wall 144 feet from foundation to overflow, across a width of 1172 feet. The wall is 127 feet thick at its base, and its masonry has a weight of 510,000 tons. The area of the lake is 1121 acres. In trying to utilize to the full the waters of the Croton River, the city of New York has built dam after dam for the purpose of storing up every gallon of water that might reach the river and there is probably no other river in the world so completely stored. The first dam, built in 1840, stored up 600 million gallons, but in the spring a good deal of water ran over the dam and was wasted. Since then many other dams, notably the New Croton dam, 260 feet high, storing 32,000 million gallons, have been built.

NEW YORK CITY'S NEW STORAGE RESERVOIR



Kensico Reservoir, with 2200 acres of water surface. This reservoir, costing about \$9,000,000, holds several months' supply for the City of New York. The maximum depth of water is 155 feet, and the construction of the massive dam has taken five years. The dam is 307 feet high and 235 feet thick at the base

The way to freedom for the rushing storm-waters

A feature of all dams is the provision for overflow, as from time to time enormous amounts of surplus water must pass the containing wall. This is usually arranged for by a waste-weir or by-wash at the end of the wall, the water falling over a series of steps to break its force, before it escapes by the lower course of the stream.

The force of falling water is very great, and even hard rock may be worn away in front of a dam unless precautions are taken to prevent it. The Austin Dam failed in 1900 because the force of the water was sufficient to tear out a part of the dam and move it bodily about 60 feet downstream. Here the whole dam acted as a waste-weir and the shape of the dam was supposed to lead the water away without harm. The necessity for careful design of dams has led some states, as Pennsylvania, to appoint state commissions, which must approve the design before a dam can be built. A rule for the safe release of storm-waters is that the sill by which they escape must be fifty feet long for every thousand acres drained.

Failures to observe the scientific principles of stability, or to allow a sufficient overflow, have led in many countries to terrible devastating bursts, especially, though not exclusively, in the case of earthen embankments.

The awful night when the waters washed away the great dam at Johnstown, Pa.

The most thrilling reservoir disaster in the last fifty years occurred in 1889 above Johnstown, Pa., the resulting water-wave being known as the Johnstown Flood. It was a small reservoir, less than a square mile in area, and the dam was a simple earth embankment 70 feet high. The immediate cause of the catastrophe was a rainfall of extraordinary severity which poured water into the reservoir in such a torrent that the waste pipes and the overflow were soon overloaded, and the water, still rising, overtopped the dam and, running down the slope, cut breaches in the bank that emptied the entire reservoir in

45 minutes. Houses, bridges, and trestles in the path of the flood were washed out, finally lodging against a stone railroad bridge in a great raft, which caught fire and burned, adding to the terror and desperation of those who looked on helplessly. There were 2235 lives lost, and property to the value of several million dollars destroyed.

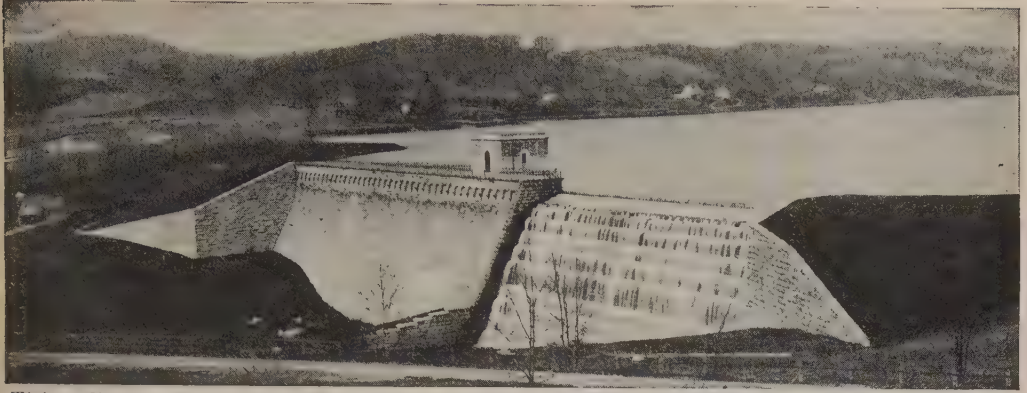
The customary method of drawing off water for consumption is by means of a valve tower. The tower is a dry well built into the reservoir, and carrying in an outer circle pipes controlled by valves through which the water can be drawn off at various levels, and turned into the supply aqueduct. The object is to use the purest and clearest water according to the amount which the reservoir contains, and that will be neither the upper nor the lower layers.

The descent of the water from origin to distributing point

The height of the storage reservoir is a matter of importance. If it is great, the fall to the distant town may be broken by intermediate distribution reservoirs to take off the "head" or pressure on the pipes, and to arrange for distribution to different heights any place that is being served. Thus the waters are let down from reservoir to reservoir, a fresh start being made from each stage, and pressure diminished.

Thus the headwaters of the Owens River, whence the long journey to Los Angeles begins, have an elevation of 3815 feet above sea level, giving a fall of nearly 3000 feet to the distributing reservoirs near the city; 2000 feet of this is within 20 miles of the city, and will be used for developing power, the sale of which it is expected will go a long way towards paying the interest on the bonds of the gigantic enterprise. The Hetch-Hetchy reservoir from which San Francisco will be supplied has an elevation of 3500 feet above the city; and in the case of New York, the Ashokan reservoir has a height of 600 feet, enough to overcome all friction and deliver the water to the top floor of city houses without pumping.

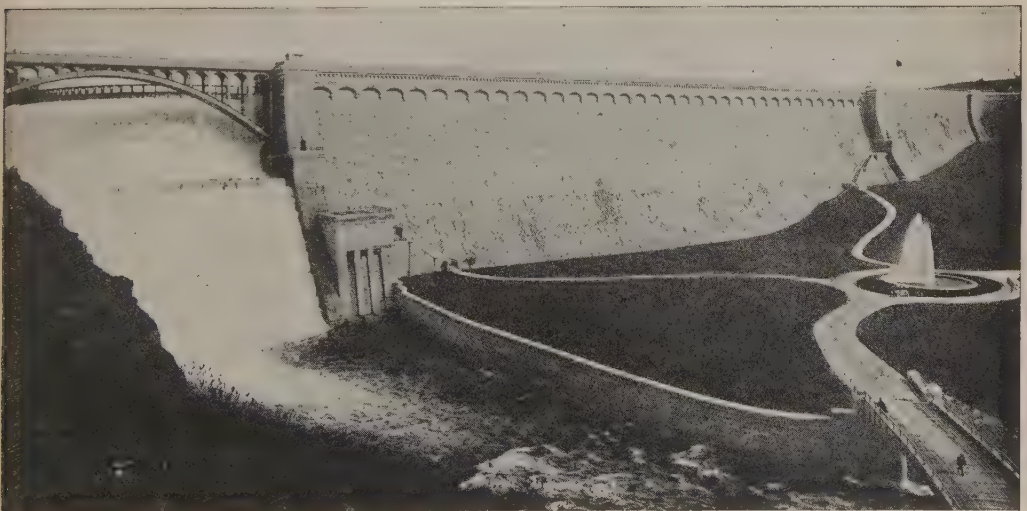
GREAT DAMS AND THEIR WASTE-WEIRS



Titicus Dam and by-wash. This structure forms a small reservoir of 725 acres on one of the west branches of the Croton River. The dam is 334 feet long and 109 feet high.



Spring time flood going over Titicus Dam spillway. So completely is the water from the Croton River conserved that the waters passing over the upper dams are caught by lower ones, a very small part only of the water escaping into the Hudson.



The Quaker Bridge or New Croton Dam, built 1892-1902, to hold back the waters of Croton Lake. The plans for this dam were studied over for 12 years by dozens of engineers to insure its safety and economy. It was the highest dam in America, the top being 262 feet above the foundation.

Nearly all American cities, however, have to pump their water, mammoth machines being used, capable of delivering 10 barrels per second. Not only, then, do these cities receive a pure water, but their gravitation supply can be used effectively at varying heights without expenditure for pumping it up to secure a head.

The water supply of a great city having been stored for consumption, some means must be adopted to clarify, and if needs be, purify it. The presence of swamps on a watershed tends to make the water a reddish yellow color, quite noticeable in a bath-tub. If farmhouses exist near the streams, there is also present the danger of contamination from barns and other outbuildings. There are many cases of epidemics where thousands of cases of typhoid fever have developed in a city through the unheeded pollution of a stream by patients suffering from that disease. Mud or silt in a water is not to be tolerated and for all these reasons some form of purification is generally essential.

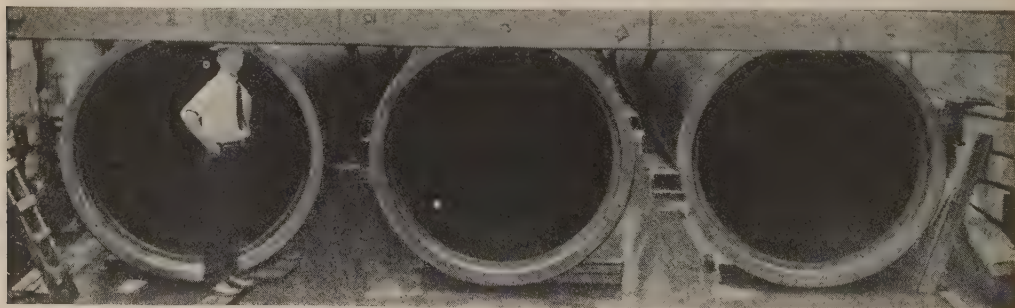
Brown, pure waters that are filtered to look clear

In the cities of the Middle West, particularly those drawing their water from the large rivers like the Ohio, Missouri, and Mississippi, the natural color of the water is a muddy brown or chocolate colored — so much discolored in fact that the very idea of bathing in such a liquid is abhorrent to strangers. In recent years a large number of such river-using cities have installed plants of various kinds to remove the very fine mud responsible for the color. St. Louis at one time treated the water

(84 million gallons a day) with chemicals, adding about 400 tons of lime and 12 tons of copperas or vitriol per day. At New Orleans (22 million gallons a day) the chemical treatment is similar, but only 6 tons of lime and 3 tons of iron are used.

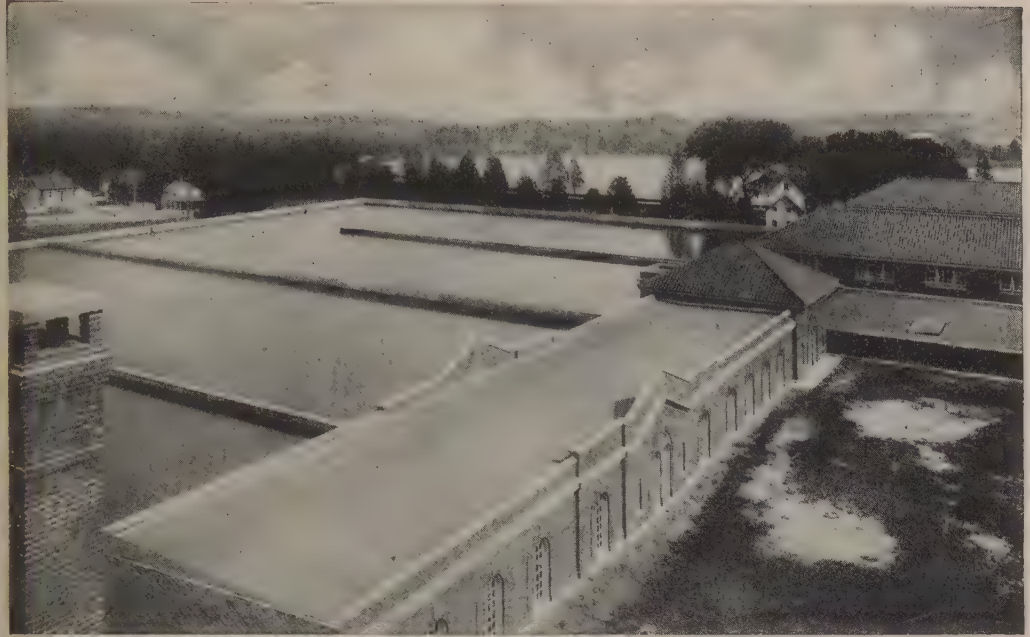
Filtration is now regarded as necessary in the case of all surface water-supplies. In some cases — as with the river water — it is essential to the securing of purity. With the purest mountain streams filtration is advisable in order to combat discoloration, and also because unfiltered water may cause growths on the interior of the iron pipes which carry it on its journey townward, and these growths greatly impede and diminish the flow. The stages of filtration are varied by the condition of the water. Often it is passed through a fine copper gauze strainer of about forty threads to the inch. Then it is allowed to stand, in sedimentation tanks, until its rougher suspended matter has subsided. After this it is drawn, or pumped, off, and passed through the filter-beds. Such a bed consists of a lower layer of coarse stone with finer layers of decreasing sizes above until a thickness is reached that can support several feet of sand.

Bacterial filtration through sand only becomes effective when a film of mud and microbes has been formed on the sand. After a time, however, the sand becomes clogged and impervious, and then a layer of it is removed and washed ready for further use. By a repetition of sand filtration contaminated waters may be made quite pure. In the case of mountain supplies, the filtration process is required rather for the sake of appearance than of purity.



THREE LINES OF 60-INCH CAST-IRON PIPE LAID UNDER THE CHARLES RIVER, CARRYING WATER BETWEEN BOSTON AND CAMBRIDGE

HOW OUR WATER SUPPLY IS FILTERED



General plan of the Baltimore filter houses, showing the large coagulating basins on the left and Lake Montebello in the background. The filters are inside the long low building.



Interior of one of the two Baltimore filter houses. On each side are eight filter units, each 32 feet wide by 54 feet long. Altogether there are 32 filters and the plant can deliver 150 million gallons of pure filtered water per day.

The long journey from the reservoirs in the hills to the water-tap

The conveyance of the water from its source to its destination is often more expensive than its impounding. In the case of the Los Angeles supply from Owens River, the cost of the conduit was 23 million dollars, the distance traversed being 233 miles.

New York City, which talked of going to the Hudson above tidewater 75 miles away, or even to Lake Ontario, 250 miles away, finally has built the Catskill Aqueduct bringing water through a concrete conduit 92 miles long, and capable of carrying enough water for the present population quite independent of the large supply from the Croton River.

Boston depends on the Nashua River, 30 miles; Washington, on the Potomac, 16 miles; St. Paul, on Rice and Centerville lakes, 20 and 10 miles away.

The aim of the engineers is to make from source to finish—from the water-tower outlet in the gathering reservoir to the distribution reservoir in the city concerned—an underground river with a gentle gradient, along a cement-lined passage, as near the surface as the contour of the country will allow.

Gentle gliding through tunneled hills and switchback piping under valleys

For this purpose a careful survey is made. But often the rise and fall of the surface will not allow a graded river inside the earth to keep just sufficiently below the soil to avoid frost and downward pressure. When there is a rise of intervening hills above the height of the water-line a tunnel must be made. Thus the Catskill Aqueduct has an aggregate length of tunnels of $13\frac{1}{2}$ miles, through which the water for New York flows as if in a channel, the longest single one, known as "Garrison", being 11,000 feet.

Again, where valleys are crossed at a lower level than the water-line, the water must be carried in pipes so as to siphon it down and up again to its former level by natural pressure, and tunneling may be necessary, as, for example, where the Catskill Aqueduct passes under the Hudson beneath the river in a steel pipe 14 feet in diameter at a depth of 1114 feet. Where pressure from a head of water is not required, and the ground will permit, the water is carried in an aqueduct or conduit lined often with concrete, and sometimes reinforced to resist subsidence or weight from above.



LOOKING UP THE HUDSON RIVER FROM THE HEIGHTS AT WEST POINT

Between the two mountains, the pipe line from the Catskills dips down under the river. The steel pipe is strongly concreted into a tunnel cut in the solid rock and, in the middle of the river, is 1114 feet below water.

SIMPLE FORMS OF SURFACE CONDUITS



A 48-INCH CAST-IRON PIPE, LAID DIRECTLY ON THE SURFACE



A KIND OF PIPE LINE MUCH USED IN THE UNITED STATES FOR CARRYING WATER

It is made out of wood strengthened by steel bands so that it can withstand as high pressure as cast-iron pipe, over which it has the advantage of being much cheaper.



THE "CUT AND COVER" TYPE

A part of the Los Angeles aqueduct at the beginning of its long reach across the Mohave Desert. The concrete top of the conduit had not been put in place when the picture was taken.

The simplest method of transit is by "cut and cover" and conduit. A trench is cut and a culvert built in it of the necessary size, the top being, because of frost, not less than thirty inches below the surface when the conduit has been finished and the earth again filled in.

Chambers reaching the surface for ingress to the conduits are built at intervals. Where cast-iron pipes are used, there may be from one to four lines and they may be as large as 7 feet in diameter. A 5-foot pipe in Cincinnati burst in 1913, drowning three men, an unusual accident however.

Pipes are dipped in pitch and oil to resist corrosion. Cut-off valves are arranged to stop the flow in case of breaks, and valves are placed in the lower portions of piped depressions to empty the pipes on occasion and remove sediment. Where there is a bend in a pipe-line the pressure is great, and the pipe is "anchored" to keep it firm in its place. The pipes are socketed into each other, and the joints packed with yarn and lead. They carry the water from one "balancing" reservoir or tank to another at

a corresponding elevation. Until recently, steel pipe has been used but little because of rapid corrosion. The city of Rochester has such faith in the protective power of an asphaltic coating that they have three lines of 3-foot steel pipe from Hemlock Lake to the city, 27 miles away. Portland, Maine, also has fairly recently built a long line of steel pipe.

The water conveyed by conduit or pipe, part of the way by one method and part of the way by the other, from reservoir to reservoir, so as to preserve the properly graded fall when it reaches the service reservoirs near its final destination at such a height as will allow it to be distributed to the topmost floors of the highest buildings, is ready to enter at once the mains of the city. Thus Kensico reservoir receives for distribution the New York supply; the Chestnut Hill reservoir the Boston supply; the Cobb's Hill reservoir the Rochester service from Hemlock Lake; San Fernando reservoirs the Los Angeles supply; and Silver Lake reservoir on Staten Island the Catskill water.

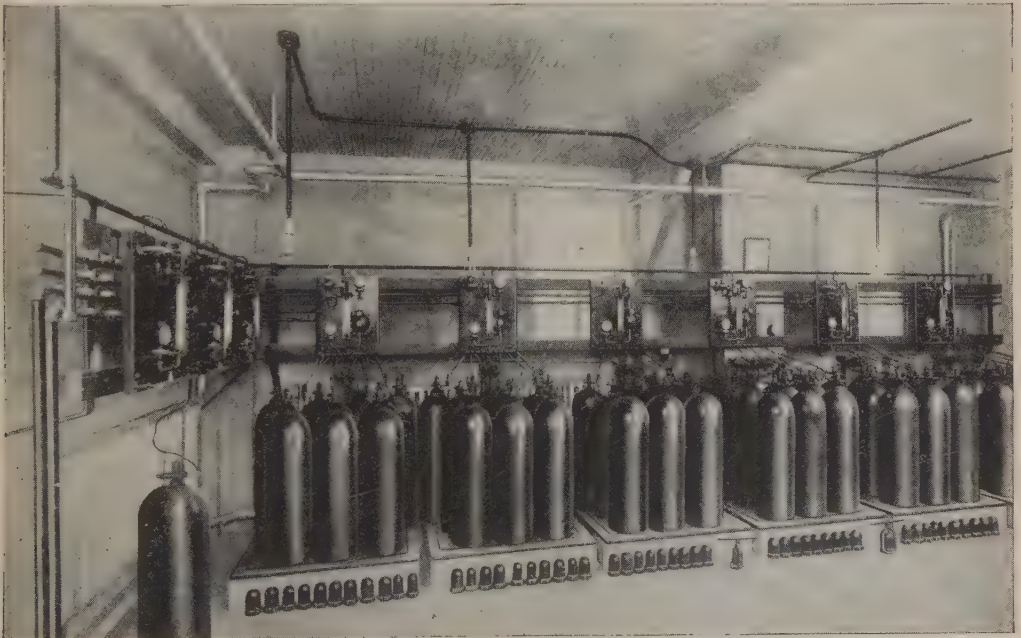
Because of the near-by presence of large rivers and lakes, most of the cities of the United States lift their water supply directly from these sources to the distributing reservoirs. Thus Buffalo, Cleveland, Detroit, Milwaukee, and Chicago pump from the great lake lying at their doors. Albany, Philadelphia, Pittsburgh, Cincinnati, and Louisville pump from the great rivers that are continually flowing by them. At first these cities, and others like them, drank the water unpurified and suffered from typhoid fever in consequence. But one after another they have reformed and have installed either filtration or sterilizing plants that are able to change the most polluted water into one of unquestionably good quality. The development of the use of chlorine either as a gas or combined with lime has provided an efficient and cheap sterilizing agent largely utilized.

There is no doubt that a great deal of expensively gathered and distributed water runs to waste. In some American and European cities from 100 to 300 gallons per head per day are expended, chiefly probably in waste. A well-organized system should not show an expenditure of over 60 gallons

and probably any expenditure above 75 gallons is waste. Wise prevision by public authorities will enable the demands of the public to be met with amazing cheapness. Though Buffalo, for example, has spent over 10 millions on waterworks, it is furnishing its inhabitants with an abundant supply at less than *two cents per ton*.

It may be taken as an average that the total cost of a great city's water-supply is from twenty to one hundred dollars per head of the population. For this amount the waters from the rain-swept hills, above the abodes of man, are banked up in reservoirs by walls of concrete which sink as deep into the earth as they rise above it, are decanted from their purest layers into cleansing beds of sand, while the surplus stores wash over the embankment and supply the mills downstream.

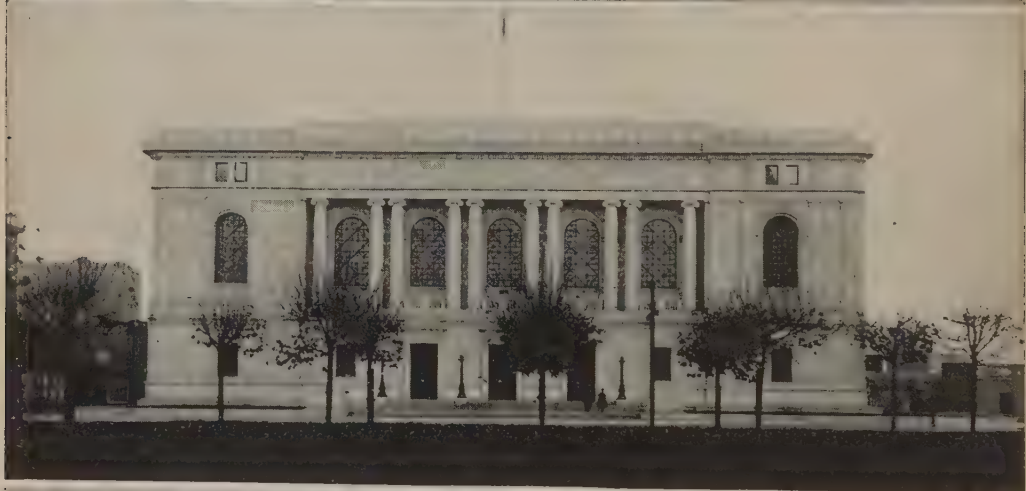
Now down dale, now up hill, seeking its level, the water is brought on its way, flowing, or by siphon pressure, to a reservoir above the city it serves, and thence is distributed through a meshwork of mains and piping to every house, and in many houses to every room, for instant use.



THE GREAT DUNWOODIE STERILIZATION PLANT

Where all the water from the Catskills for New York City is sterilized. Each of the cylinders contains compressed chlorine gas that is allowed to escape slowly into the water where it almost instantly kills all the bacteria present and yet has no effect on the good quality of the water.

SAN FRANCISCO'S FINE CIVIC CENTER



Photos by City Engineer

CITY HALL — PUBLIC LIBRARY — AUDITORIUM

THE IDEAL MODERN CITY

The Great Common Benefits a Municipality
Should Provide, or Insist on, for All of Its Citizens

THINGS WE HAVE OR MAY HAVE SOON

FROM the day when the families of men began to live together for the sake of defense, or for coöperation in hunting or husbandry, the problems of civic government must have existed in elementary forms. The earliest community would have its internal public duties, as well as the external duties of defense, and the securing of the means of subsistence; and at every stage in advancing civilization the growing complexity of these duties would be apparent, until now, wherever we live, the duties, rights, assistances, and restrictions of civic organization hem us in, and, indeed, if we live in cities, become a major part of our lives. Objection to this state of things is entirely useless, for we cannot alter it. Whether we would have it so or not, we are made one family by the cement of the taxes; and the most practical course open to us is to ask how we can perfect that part of our lives which is lived in common with our neighbors. Is it possible to make for ourselves an ideal city? If so, what should its characteristics be?

An ideal city can never be founded on any other bases than the intelligent idealism, foresight and local pride of the citizens. In this respect even piety takes a second place, for knowledge, at present, is broader than piety. "Purify the hearts of your people and the city will be clean" is only a half-truth, for men may be the salt of the earth as far as personal goodness is concerned, and yet, unawares, may be, in some respects, bad citizens. Like Tennyson's village wife, they may attribute the effects of their poisonous sewers to the "will of the Lord".

Given that a city has the power of self-management, and values such power highly, so that all its affairs are matters of keen general interest, and presuming that its best men of business are willing to undertake the administration in a spirit of hearty local pride, then there is no reason why the city should not gradually improve itself into the position of an ideal city, supporting vigorously every institution that is necessary from either a local or a national point of view. What must be the aims that will lead to that end?

Almost without exception, whoever talks about the management of great cities begins with health. The preservation of public health is the subject of the first paragraph in the address of nineteen would-be administrators out of twenty. And very properly so, for health, important in itself, is inextricably interwoven with almost all other subjects of high civic importance, as, for example, with education, housing, recreative exercise, transportation from the crowded districts to the country, and wise and adequate feeding, as well as with formal sanitation. Indeed, half, or more, of the necessities that go to the making of the ideal city might be discussed under the one heading of health.

Now, the first of all desirable things in making the ideal city is space. Unfortunately, it was only late in the day that this fact of prime importance was realized, for in many times and lands other reasons than those of health determined the building of cities. The ruling thought for centuries was defense. The smaller the area to be defended the better, and the houses were crowded on a minimum of ground.

Or, in tropical countries, the narrow street, flanked by tall houses with overhanging roofs, gave welcome shade. Or, again, where earthquakes are not infrequent, and where houses are built, as in Japan, so that they may fall without doing much damage, the building often binds many dwellings firmly together on arches, till they stand in solid blocks which only such a rending quake as that in Yokohama in 1923 can wholly demolish. Each of these reasons for crowding houses on the smallest space and welding them together may be seen in some Italian cities, as, for example, in the older parts of Genoa. It is true that the Romans understood the value of space in building, but the tradition left to modern times by the Middle Ages is one of restriction, and the center of every great European city has an inherited congestion that gives the limited land a tenfold value. Yet, from the point of view of health, the ideal city must have space, both as regards its general plan and its individual houses.

The possibility of every city's approaching the ideal without ruinous cost

So far as the older cities are concerned, central change can only come gradually through improvement schemes, on grounds of expense, the preservation of valuable sites, and respect for traditions; but town-planning arrangements are now possible everywhere in suburban areas; and indirectly they may enormously relieve central congestion, and give business space by drawing off redundant population, always provided there are rapid, ample and cheap means of transit in and out of the city. Under these circumstances, there is no excuse for saying that any attempts to approach the ideal city are impossible. The possibility exists everywhere, and expense is not a bar. The things needed are will power and ideas. As a matter of fact municipal action for the improvement of a city—in proportion to its business possibilities—whether the improvement affects the business center or the suburban residential quarters, is invariably in the long run a paying enterprise. The bogey of cost is only a bogey, if the scheme be well devised in view of local conditions.

Why should not municipal and private enterprise run in friendly competition?

One general consideration deserves mention before we inquire respecting the aims in detail of an ideal city in relation to health, and that is whether municipal schemes of improvement should be positive and formative on the part of a municipality, or be negative and restrictive. In other words, is the new spirit a good spirit when it leads a community to look ahead, to make plans, to welcome ideas, to risk something in experiment, and to say: "We will project improvements that will make some part of this city approach the ideal a quarter of a century ahead"? Or is it better to follow the old plan, and to say: "We will leave improvement to individual enterprise and desire for gain, seeking it only by demanding, through by-laws, a minimum of efficiency. We will say: 'Houses here must conform at least to such and such dimensions, with so much open space, frontage, roadway, etc.,' and thus insure reasonable improvement without risk"?

Probably the wisest answer to these questions may be put in the form of another question: Is there any reason why both these methods of improvement should not be adopted? Why should not an intelligently energetic municipality both improve the town, on its own account, and also offer a fair field for private enterprise to show its initiative and successful accomplishment? The competition will be good in any case, and will compel all those who plan and build to give good value, without the burden of extravagant expense. Why cannot a city not only warn the remiss but show the way on its own account?

The ideal plan of an obscure town in the Far West

If we were to select a town plan that most compendiously shows, in outline, what an ideal city should be, we should bring it from quite an unexpected quarter. We should go near the frontier line of Canada, where the Mormons have crossed over from the United States and established one of their communities. There, on the prairie, they have built the town of Sterling.

Roughly, the scheme of it is the scheme of a cart wheel, with the streets converging like the spokes, to a large central open space, like the hub. In the middle of this central part, which is the playing-piece of the town, stands the communal building — town hall, temple, meeting place, concert hall, scene of social gatherings. Every street leads down to the happy playing ground of the children, and across to the center of all social and higher activities. Along the streets passes running water, for the town is a center of irrigation; and the houses are separated, each with its surrounding garden space.

Here, then, we find, evolved by a contented religious sect, a town that answers fairly to the ideal for playing and pleasure spaces, and also for healthy living spaces around, if not in, the houses; and nowhere in the civilized lands is a fresh start on these lines, on the outskirts of cities, impossible or likely to be unremunerative.

Is it not a curious comment on the slowness of mankind, even in these supposedly headlong days, that we have not only failed to decide, save in a few conspicuous instances, what an ideal residential quarter should be like, but we have not even, after a million experiments, constructed the ideal house? Only bit by bit are we learning the essentials of house building, and we do not yet dare to look twenty years ahead. We are speaking, of course, of one or two-family houses. What are the essentials made manifest since the days when the house was regarded as a place where each family could cower in stuffy seclusion?

Houses, ideally, are built to admit an amplitude of air, light and water, and to keep out damp; and they will be built, before long, to admit heat and power. In their building, regard should be given to work, in the kitchen; to rest, in the

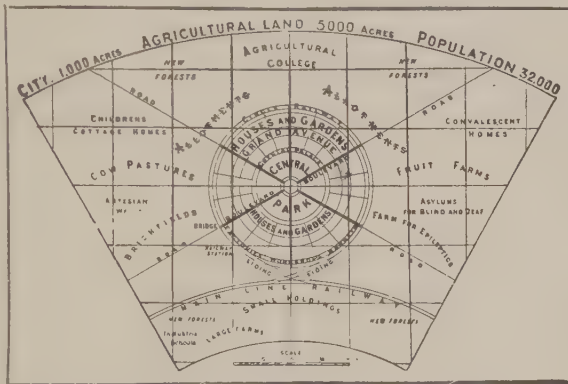
living-rooms; and to sickness, in one or more of the sleeping-rooms — for sickness will come. Of these needs the most immediate, no doubt, is fresh air, the least understood is light, and the most variedly useful is water, inasmuch as it is the scavenger of the house, as well as the outward cleanser and the quencher of thirst.

It should be impossible in any city to build a house that does not have a daily bath of sunlight, an abundant flushing by a through draught of air, and an ample supply of water for drinking and baths, with sewer connections for refuse. Anything short of this means danger to the community, and an absence of the conditions which make education in health-

preservation possible. Health and education, by the way, interlock at many points, and together cover nearly the whole range of social organization.

In this country, where fuel is generally cheap, and the wages of labor also relatively high, we have not

yet been forced to appreciate the blessings of adequate warmth in winter. In Europe, especially in continental Europe, the acute pinch of cold is universal among all the poorer people in the cities, and with the progressive exhaustion of our phenomenal resources in coal the problem will become more and more pressing here also. Even now the dread of cold is the cause of much of the evil of our slums, for the cost of heat and the necessity for economizing it is an important motive to overcrowding. The poison of bad air is welcomed by poverty in preference to the cold, and so rooms are hermetically sealed against ventilation. The lure of the saloon was largely its warmth. Now there is no more reason why society should permit homes to be inadequately heated than that it should allow them to be unsanitary in other respects.



From Ebenezer Howard's "Tomorrow."

DIAGRAM OF AN IMAGINARY GARDEN CITY

Need for a highway for heat and power, as well as light and air, into every house

The piping, or wiring, of the house has now become a necessity as far as water and light (either gas or electricity or both) are concerned, and in most cases for telephonic purposes; and the probability is that the near future will see similar arrangements made not only for the distribution of heat but also of power. In one way or another the next generation will doubtless be familiar with the cheap production and distribution of power on a scale hitherto undreamed of. Not only will workshops and places of business be able to switch on a very cheap supply of mechanical force, but it will be available in every house where a substantial amount of work or cleaning has to be done. What will be needed for men and women will be intelligent direction of mechanical operations, and not muscular exertion. When that time comes, the necessity for packing people into crowded factories will have passed away largely, and cities may spread far and wide in the fresh air, saved from a cramped industrialism, as they have been from the crush demanded in the Middle Ages by self-defense.

The unending duty of caring for the sick and the incapable

But however healthy the city may be because of its open spaces and its well-planned and fully served houses, there will still be the old need — though in diminishing proportions — for hospital accommodation for the sick and sufferers from accident, and for care on behalf of the weakly and incompetent of all ages, even when cripples have been dealt with by the vocational training experts, and the mentally defective by proper institutions. And this work, in an ideal city, would certainly not be left to the chance impulses of sympathetic contributors. No doubt such benevolence is very fine, as far as it goes, but it is a bulwark for the stingy, who will never pay their share until they are legally compelled.

As long ago as the "Utopia" of Sir Thomas More, spacious hospital accommodation for all sick, with the best medical

attention, was demanded, in terms that would be acceptable today; and quite on the same level is the care of the aged whom no pension scheme can touch, and the incompetent, who abound. People who talk without knowledge of the weakness of the poorhouse system generally include in the sum of their ignorance a complete misunderstanding of the main reason why a large proportion of the inmates are "a charge on the public". It is a result of sheer incapacity. Go into any poorhouse assembly of aged men, and, sitting behind them, look at their heads. A vision of inherent ineffectuality is what meets the eye. Not one in ten can ever have played a man's full part in the world of men. In our ideal city, the sick must be healed — in hospitals, if their sickness is a danger to the rest of the community — and the incompetent must be sympathetically cared for; hence the hospital and something like the poorhouse will stand.

Street-paving in cities as a barometer of health statistics

One of the health conditions of the ideal city is, of course, well-paved streets. This question is usually regarded as affecting primarily the business interest of the city — rapid communication, and so forth — but it is almost equally a matter of sanitation, for the rapid and complete surface drainage of a street, impossible unless the paving is sound, is almost as important as the sewage system for carrying away impurities underneath the ground. The health statistics of any city give an instant response to improvement in street-paving with a drop from a higher to a lower death-rate — a most significant parallelism. The most up-to-date sewage system fails in part if bad paving, or no paving, allows the upper layers of the earth to be saturated with poisons.

After health, and indeed with it in many ways, ranks education in our survey of the demands of an ideal city. An education that never ends is now regarded, happily, as a civic duty accompanying life through every stage. As will be pointed out in our eugenics chapters, it certainly begins before parenthood, in view of the

A GREAT CITY'S FIGHT WITH DISEASE



GROUP OF INFIRMARY BUILDINGS



ADMINISTRATION BUILDING



TYPE OF CHILDREN'S COTTAGE



TYPE OF ADULT PATIENTS' COTTAGE

THE CHICAGO MUNICIPAL TUBERCULOSIS SANITARIUM

The upper picture is from a photograph of Henry Fuermann & Son, the other three are by Kaufmann & Fabry Company.

coming child-life. Before, at and after motherhood the state already accepts a certain responsibility which it can only make good by giving education in child-rearing. The days of earliest infancy are now days of watchfulness in any great civic community, and the visiting nurse is beginning to be acknowledged as a friend. By the doctoring of sickly infants, by lectures to mothers, by the provision of pure food of a suitable nature, all self-respecting cities are competing for a good record in the preservation of infant life; and the ideal city is bound to be foremost in this most important of cultures.

The public duty of conserving child-life without intermission

What shall happen in the post-infant days or pre-school days, when the "home-child" passes from under the surveillance of the city nurse, but has not come under the eye of the school teacher, is a problem not yet fully solved, but fortunately on the way to solution. Froebel's great invention of the kindergarten, when taken over and developed by public authority, can make a much larger contribution than it now does to this result. A recent innovation of great promise is the municipal day-nursery, where proper care and wholesome surroundings are provided during work-hours for the helpless children of mothers who are daily forced to go away from home to earn a livelihood. The ideal city will never lose sight of its child-life, but will carry out enthusiastically the new idea of education and of the relation of the State to the child, which democracy has given to the world.

What is that new idea? It is not that the State shall assist in the education of the children of Brown, Jones and Robinson, or coerce Brown, Jones and Robinson, if need be, into allowing their children to be more or less schooled, but it is that the whole of the child-life of the nation shall be regarded in the bulk as so much invaluable material to be registered, examined, understood, developed, physically and mentally, and trained most suitably past adolescence. What was a more or less casual parental duty becomes a national task, in which each separate city and town assists.

Making the school a training ground for later life

The great changes in modern conditions, especially the growth of cities themselves, have developed and broadened another gap, at the close of the school period, between the school and life. Educators are making good headway in devising means for smoothing this transition also, and making the school a sort of natural ante-chamber to the work the child will subsequently take up. The need for changes in the educational system has become a necessity with recent legislation preventing the entry of children into wage-earning occupations before sixteen or eighteen years of age. Professor John Dewey should be particularly mentioned for his great work in devising a system of schooling which, because it interests the child and fits him to enter naturally into a more satisfactory and useful place, will hold him until he is ready to take his place in the social and industrial system.

The full training of all ability, to enrich the national life

The educational ideal of the ideal city must be to give freely to every child, according to its ability, and irrespective of its origin, a full opportunity of developing whatever powers it may be endowed with. Nothing less than that utilization of all the latent forces of national manhood justifies a national scheme of education paid for by all.

There is a growing sentiment amongst teachers in the great state universities in our country that admission should be based upon competitive examinations, and that to place higher education upon a really equalitarian basis, the state should largely support those who are successful in the examinations throughout their university course. Those who lack the power to pass the tests but who would like the adornment of a cultural education might then secure it at privately endowed schools. The generality of the taxpayers would not then be contributing to the schooling of persons who are extremely unlikely to make any return to society for its expendi-

ture. Whatever names may be given to different forms of education — secondary, technical or university — each form of study must be open freely to all who are so gifted that they can take advantage of that form of study, and thereby be prepared to enrich the national life. The motto of the ideal city in education must be — to every scholar his full natural chance. If the facilities for this complete education are not available within a reasonable distance, they should be established.

Since the Great War there has been a remarkable growth in the municipally supported college. Quite often, as in the case of Detroit, the institution is made to embrace the first two academic years, and is called a "Junior College". Such schools may be very economically established by the fuller utilization of higher school buildings. Some of the most notable instances of such schools are those in Cincinnati and Akron.

Outside of school or classroom work of all types, the ideal city will have many agencies and institutions that are educative in their main effects. Lectureships will exist in wide variety, appealing to all kinds of audiences. Museums will suggest and furnish facilities for lines of study; picture-galleries will give and take with other similar galleries, till a broad idea of art in its many manifestations will be presented to the citizens.

Curmudgeon cities that cherish their public pictures for their own sole use

In art, happily, there are few cities that take the curmudgeon view, and try to keep their treasures to themselves, or to set up the absurd claim that the pictures they happen to possess are sufficient for the satisfaction of their citizens' inquiries and tastes. This curmudgeon view is not impossible, perhaps not unnatural, to cities which at great expense have placed themselves far in advance of their neighbors, but civic pride and public spirit generally overcome selfishness.

Some debatable points that arise in the organization of the ideal city are the service of books to free libraries, and the question whether a municipal theater is desirable.

In these days of universal cheap fiction, it is generally felt that, apart from the novels which are an inalienable part of the literary history of the country, there is no true need for publicly provided story-telling, and, indeed, that the provision of the novels of the hour is inimical to the study of books of value and novels that have stood the test of time. Indeed, it may be questioned whether in any direction it is a duty of the community to provide mere amusement. Perhaps the dividing line may be most clearly seen in the case of the theater. The drama, which is a genuine study of life and character, and illustrates the actor's art, would take a high place in the scheme of a city's education, but on the same plane there would be no place for the frivolities of the hour that close their influence with an empty laugh. The duty of the community in this respect begins and ends with art — a distinction not always understood, as many a popular municipal program proves.

The civic duty of provision for manly exercises that need space

A whole set of legitimate civic enterprises may be mentioned which belong partly to the department of public health and partly to education. For example, the provision of baths is essential for the teaching of swimming even after every house is provided with a bath and abundance of water and heat. For swimming holds its own both from the points of view of health and of education. Again, parks are a border-line requirement in great cities, called for alike by health and education, and are very inadequately planned if they keep only one of these great aims in sight. The same may be said of all arrangements for drill and athletics — arrangements that might be far more vigorously developed than has been customary in the past. If we examine the commonest of taunts against the townsman of today, it is that he prefers watching games to playing them. But does he? Is not the true explanation to be found in the fact that he has nowhere to play beyond the spaces already fully occupied? In all wise town-planning of the future a look-out must be kept for arenas for physical development.

A question that trenches on health and education and taste is: "Would an ideal city provide gardens for cultivation by those who earnestly desire them?" It may be assumed that any such provision would be free of cost to the public funds, for the gardener everywhere is willing to pay the modest price of his pleasure. It may be said that only a small percentage of the inhabitants desire gardens, or would cultivate them in such a way as to make them an attractive sight, and that towards such a minority the rest of the community have no special duty. But is that so? It must be remembered that on the outskirts of a city it is only by municipal action that allotment gardens can be certainly arranged and kept, and even then perhaps not permanently. But any energetic municipal corporation undertaking the full duties of city government will be sure to have land on its hands suitable for allotments — as, for example, land reserved for cemeteries — so that provision of a certain number of gardens is no risk. But behind these considerations lies the fact that many men in cities have a great desire to get back in their leisure to direct touch with the earth's fruitfulness, and take a wistful delight in the production of flowers and vegetables, so that the show from a set of allotment gardens is a sight of exceptional beauty and deep significance. It answers to a healthy primal instinct a city may well preserve.

The extension of public care to the rearing of the nation's children, through every properly equipped office of a Medical Health Officer, has brought organized mankind face to face with the fact that milk is a simple prime necessity for the continuance of the race, and must be provided in a pure form. Indeed, it is being so provided in many a poor quarter, through the public authorities, with an extraordinarily good effect on the health of infants; and the provision of pure milk for all could be readily organized by the city, with much economy in the labor of distribution. In fact, eugenically and economically the milk trade is essentially a branch of the public health department. No other provision of food stands on the same footing, for none is so elementarily simple. There is but one milk

to which all tastes must conform, whereas in every other food taste plays an enormous part in the demand, and there is no standardization such as nature herself provides in milk.

Associated with the food supply is the problem of marketing which has really become acute in recent years. A large proportion of American cities do not so much as own municipal markets, though the privilege of doing so was one of the first possessions of the historic towns, obtained by grant of the English Crown. Though much of the public outcry against "the middleman" is misplaced, there undoubtedly is much waste of foodstuffs and unnecessary increase in price between producer and consumer. Some use of the parcel post system is being made to relieve conditions, and many cities are developing public market facilities. Notable efforts have been undertaken in Washington, in co-operation with the Post-Office Department.

If we search for the real basis of the many joint duties undertaken by municipalities in the name of the citizens on behalf of all, we shall find it in the care of the roads. It was the making and mending of roads that first linked men together in common action, when the need for clustering in self-defense had passed. Tithes were levied for the maintenance of the church, the poor, and the roads and bridges. Apart from religion and philanthropy, then, the road was the first object of communal coöperation, and to the present day it gives the municipality a sort of central hold on enterprises of general utility. Thus the argument for municipalities owning and working the street railways is strengthened by the fact that they are a quicker means of doing what the road was designed to do — namely, to facilitate the passage of citizens from point to point within the area of common government — and it is enforced by the weighty consideration that whoever manages the car-lines must to a large extent control the streets — their making, repairs and traffic. The same argument holds good with respect to all the wires, pipes and mains that pass under the common highway. They should be under the management of the owners

CIVIC CENTER OF COLORADO'S CAPITAL



OPEN AIR THEATER AND COLONNADE OF CIVIC BENEFACTORS FROM PUBLIC LIBRARY



Photos L. C. McClure

STATE HOUSE SEEN THROUGH THE COLONNADE OF OPEN AIR THEATER

CENTERS OF CIVIC PRIDE AND ARDOR



THE TOWN HALL AT MANCHESTER, THE SECOND LARGEST CITY IN ENGLAND



THE TOWN HALL AT CARDIFF, THE PRINCIPAL TOWN OF WALES

of the highway; and the enterprises with which they are concerned may with general advantage be municipally owned as by their very nature they must constitute a monopoly, for competitive opening of highways would be utterly impracticable. Competitive business, racing of wheeled vehicles along the surface of such common public roads, is bad enough. The principle underlying sound municipalization seems to be that the community should undertake for itself all those simple, homogeneous enterprises which can be definitely located, as with the bringing of wires and pipes into houses, of the passage of pipes under, or rails over roads.

kinds of evil thrive in the dark. Then, too, parks, museums, picture-galleries, and especially a general public use of them under conditions that exact some formality, places them under the guardianship of the public as their property, and tends to set up a high standard of carefulness and attractive behavior. The lessons that are in the air are more potent, as a rule, than the lessons of the schools and of formal moralists.

And for that reason one of the most important considerations in the upbuilding of an ideal modern city should be the establishment of a civic center, for social as well as administrative purposes, a town hall to



Photo Gabriel Moulin

CALIFORNIA STATE BUILDING
In San Francisco's Civic Center.

What has been said so far of the modern ideal city — each feature already realized as practicable in some instances — has been almost entirely of a material character. What about the higher products of human intercourse? In civic government has religion, for example, no formal place? What about the amenities of life, the cultivation of a sense of beauty, the inculcation of pleasing manners? To this objection against the seeming exclusion of the highest concerns, it may be urged that the higher influence of a wise material government is far greater than is sometimes imagined. For example, the abundant lighting of a city helps not only in the guardianship of property, but has a distinct effect on morality, and some bearing on manners. All

which, sooner or later, every section of the community will be invited, as to a place that is theirs by general right, but that honors them by an invitation. The stimulation given to civic spirit by receptions attended by all types of citizens, the leading business men and city fathers meeting shopkeepers, politicians, charitable society leaders, religious workers, and representative men and women of the rank and file of industry cannot be overestimated. Such gatherings in the common home of the citizens, by invitation, as occasion serves, and with due formality, have effects of a far-reaching character. It is the visible sign of common citizenship, and adds dignity, responsibility and reality to local public life.

THE GRAND CANYON'S FIRST EXPLORER



SENTINEL POINT, ON THE RIM OF THE GRAND CANYON OF THE COLORADO RIVER, IN ARIZONA



MEMORIAL TO MAJOR JOHN WESLEY POWELL, ERECTED BY THE GOVERNMENT ON SENTINEL POINT;
UPON THE ALTAR THAT CROWNS IT WILL BLAZE CEREMONIAL FIRES
Photos by El Tovar Studio, from the National Park Service, U. S. Department of the Interior.

GEOLOGISTS III

JOHN WESLEY POWELL — THE GEOLOGIST WHO FIRST EXPLORED THE GRAND CANYON OF THE COLORADO

ROLLIN D. SALISBURY — INTERNATIONAL AUTHORITY ON GEOLOGIC AND GEOGRAPHIC SUBJECTS

ADAM SEDGWICK — AN EXPERT IN STRATIFICATION

BENJAMIN SILLIMAN — THE NESTOR OF AMERICAN SCIENCE

JOHN WESLEY POWELL

The Geologist Who First Explored the Grand Canyon of the Colorado

JOHN WESLEY POWELL, American geologist and explorer, was born at Mount Morris, N. Y., March 24, 1834, and was educated at the Wesleyan College at Wheaton, Ill., and at Illinois and Oberlin Colleges. During the Civil War he enlisted as a private in the Union Army and was quickly promoted. In the battle of Shiloh he lost his right arm, but continued in the service until the close of the war, when he was appointed professor of geology in Illinois Wesleyan University at Bloomington and two years later accepted a similar position in Illinois Normal University. In 1867 he commenced a series of expeditions into the Rocky Mountains, and the canyons of the Green and Colorado rivers, and he and his party were the first human beings of any color or condition known to have made the passage of the Grand Canyon. They started from Green River, Wyoming, May 24, 1869, and reached the mouth of the Virgin, August 30th. His survey filled an important mission in the scientific investigation of a vast and little known territory. Below the juncture of the Green and Grand rivers with the Colorado the river passes through "what is in some respects the most remarkable region on earth, not only for its natural scenery, but also for the great interest which it possesses for geologists, as it gives on a mighty scale the clearest exemplification of the action of erosive forces in shaping

EDUARD SUSS — FOUNDER OF THE NEW GEOLOGY

ABRAHAM GOTTLÖB WERNER — THE FORMATION OF ROCKS IN WATER

ALEXANDER WINCHELL — PHILOSOPHER AND GEOLOGIST

NEWTON H. WINCHELL — GEOLOGIST OF MINNESOTA AND THE NORTHWEST

KARL ALFRED VON ZITTEL — A FAMOUS PALEONTOLOGIST

the contour of the land and presents structural sections of vast extent unmasked by vegetation". In the Eocene epoch the whole region of Arizona, Utah and Nevada was subjected to a vast upheaval and what was formerly the bottom of the ocean was raised to a height of more than 10,000 feet above the sea level. This region, consisting chiefly of horizontal strata of the Palæozoic and Mesozoic systems, was subjected to extensive denudation by air and water, and again to successive upheavals accompanied by volcanic action. The result of the uplifting and erosion was the washing away of the weaker and softer strata while those rocks that were protected by harder layers were left standing as extensive plateaus with precipitous escarpments. The precipitation was heaviest on the high mountains, diminishing according to latitude. Denudation therefore proceeds much more rapidly along stream beds, even where these, as is frequently the case, are dry for a great part of the time, with "the result that the stream beds are depressed to great depths below the surrounding levels, giving rise to a multitude of profound gorges or canyons". The longest and deepest of these remarkable chasms is the Grand Canyon of the Colorado in Arizona, the exploration of which was feared by the Indians, refused by the hardiest frontiersmen and left for a geologist and a school teacher, a one-armed veteran of the Civil War, John Wesley Powell, afterwards director of the United States Geological Survey, to dare and to accomplish.

This was in 1869. Nine men went with him in four boats. There proved to be no impassable whirlpools in the Grand Canyon, no underground passages and no cataracts. But the trip was hazardous in the extreme. The adventurers faced the unknown at every bend, daily—sometimes several times daily—embarking upon swift rapids without guessing upon what rocks or in what great falls they might terminate. Continually they upset. They were unable to build fires sometimes for days at a stretch. Four men deserted, hoping to climb the walls, and were never heard from again—and this happened the very day before Major Powell and his faithful half dozen floated clear of the Grand Canyon into safety.

Powell's journey through this wonderful region, far from any base of supplies, rendered his name famous in the scientific world, for he gathered much valuable information on the geology of the district and made a special study of the Indians and their languages. From 1870 to 1879 Powell was employed by the United States in making geological and topographical surveys of the Colorado River and its tributaries and of the territory west of the one hundredth meridian. Congress voted supplies and Powell made his second voyage down the Colorado River. There were four expeditions at this time popularly known as the King, Hayden, Wheeler and Powell surveys, under the direction of George W. Wheeler and John W. Powell. As the scope of operations extended, however, it became evident that the work could be unified to advantage, and a plan proposed by the National Academy of Sciences was finally adopted by Congress in 1879, and independent surveys discontinued. The control of the new organization, known as the United States Geological and Geographical Survey, was placed in the hands of a director, who was required to submit an annual report of plans and operations of the survey to the Secretary of the Interior. Clarence King was the first director and upon his resignation in 1881 Powell was appointed to the position, which he occupied until 1894, and in which he did much valu-

able work in organizing surveys and arranging collected facts. Powell secured a great deal of ethnological material regarding the American Indians, sending it in to the Smithsonian Institution, and later, in 1876, this was published as "Contributions to North American Ethnology".

In 1897 he became director of the Bureau of Ethnology, and devoted himself to psychological and philosophical studies, in which field he published "Truth and Error". His books include: "Exploration of the Colorado River of the West and Its Tributaries" (1875); "Report on the Geology of the Uinta Mountains" (1876); "Report on the Arid Region of the United States" (1879); "Introduction to the Study of Indian Languages" (1880); "Studies in Sociology" (1887); "Canyons of the Colorado" (1893); "Physiographic Processes, Physiographic Features, and Physiographic Regions of the United States" (1895). Powell was a member of most of the important scientific societies of the United States, and served as president of the Anthropological Society of Washington, and in 1888 of the American Association for the Advancement of Science. He was the recipient of many honors from foreign societies, among them the Cuvier prize awarded to himself and his companions. "Especially important were his observations on what is now termed the 'Uinta type' of mountain structure; a broad, flattened anticline from which the strata descend steeply into bordering low grounds and quickly resume their horizontality." He died in 1902 at Haven, Mo.

ROLLIN D. SALISBURY

International Authority on Geologic and Geographic Subjects

ROLLIN D. SALISBURY, one of the most brilliant of the American geologists who have, in the present generation, created the science of physiography, which deals with the surface features of the earth, was born at Spring Prairie, Wisconsin, on August 17, 1858. He was graduated at Beloit College in 1881. After acting as tutor for a year he became professor of geology there in 1884, and remained until he was appointed, in 1891, professor

of general and geographic geology in the University of Wisconsin. In 1892 he accepted the chair of geographical geology in the University of Chicago, and here in 1899 he became dean of the Ogden School of Science and in 1903 head of the department of geography.

Professor Salisbury became a member of the United States Geological Survey in 1882, acting for twelve years as assistant, and from 1894 until his death as head of the glacial division. After 1891 he also had the direction of the Pleistocene division for New Jersey. His studies were not altogether confined to America, for during his professorship at Beloit he spent a year at Heidelberg and other European centers of learning. His most important works, however, deal with features observed in the United States.

In 1909, in an important paper on "The Physical Geography of the Pleistocene", Professor Salisbury made a study of great interest on the effect of altitude on climate, and therefore on geological processes, doing justice, for the first time, to the increased erosion in high altitudes. He showed, however, that the decay of rocks, accelerated by increased altitude, is diminished, on the other hand, by the lowering of the temperature and by the protection of surfaces with sheets of ice.

In his valuable textbook of "Physiography" (1907), Professor Salisbury defined the science which he had made his own: "Physiography has to do primarily with the surface of the lithosphere, and with the relations of air and water to it. Its field is the zone of contact of air and water with land, and of air with water." He distinguishes also between geology and physiography: "Geology has to do with the history of the earth, while physiography has to do only with a late chapter of that history." Professor Salisbury was the author of "The Physical Geography of New Jersey" (1898), "The Elements of Geography" (1912), "Modern Geography for High Schools" (1913) and joint author with T. C. Chamberlin of "Geology" (3 vols., 1904-09) and "Introductory Geology" (1914). He died in Chicago, August 15, 1922.

ADAM SEDGWICK An Expert in Stratification

ADAM SEDGWICK was born on March 22, 1785, at Dent, Yorkshire, England, where his father was curate and then head master of the grammar school, at which, until the age of sixteen, Sedgwick received his education. He was graduated in 1808 from Trinity College, Cambridge, of which he was later made a fellow. In 1816 he received ordination.

In 1818, though he knew little, and cared little, about the subject, Sedgwick was elected professor of geology. Much ill-



ADAM SEDGWICK

feeling was aroused by the choice, which was, however, determined by the strong character and personal power which, even at that age, were evident in the young man. Sedgwick immediately set to work to acquire first-hand knowledge of his subject, at that time very little known or studied in England. The pioneer work of Hutton, William Smith and others had been developed only by French and German students, and his untiring services as observer, teacher and courageous advocate of scientific progress were of inestimable benefit to the advance of the science. His geological expeditions in Devon and Cornwall convinced him that the theory

of a simultaneous origin for all fossils, in those days generally believed to be all the result of the Deluge, was absurd; the fossils which he found, for instance, in the Plymouth corals being manifestly older than those of the Limestone, and, moreover, of a totally different character.

In 1829 Sedgwick traveled with Murchison in the Austrian and Bavarian Alps, making detailed studies of the stratigraphy of the district, and in 1831 they carried out similar investigations in Wales. Their researches were then continued in the Devon and Dartmoor district, until in 1839 they published their classification of the transitional strata between the crystalline schists and the coal measures. The upper series, examined by Murchison, were called by him "Silurian", and he divided them into Upper and Lower; below these came the series specially studied by Sedgwick, and called by him "Cambrian"; and a third newly identified system of strata received the name of "Devonian". Murchison's further researches on the Palæozoic formations led him to the conclusion that Sedgwick's Cambrian system was not at all distinct, but was a part of the Silurian, and this result he published in 1842. Sedgwick, convinced of the accuracy of his classification, and hurt by Murchison's denial of it, set out on more elaborate investigations, and in 1852 produced further results in support of his views. The controversy lasted for years, and Sedgwick's theory did not receive official recognition until after his death.

Other important stratigraphical researches undertaken by Sedgwick were those among the older rocks of the Lake District, begun in 1822, and occupying a great part of his life, and on the New Red Sandstone of the North of England. He always maintained the necessity of a detailed examination of the stratification of a district in order to correctly read its geological history, for a study of the fossil deposits was, he asserted, inadequate.

Sedgwick got together a geological collection worthy of the university and secured the erection of the necessary building for it. He continued to lecture until 1870, and died at Cambridge on January 27, 1873.

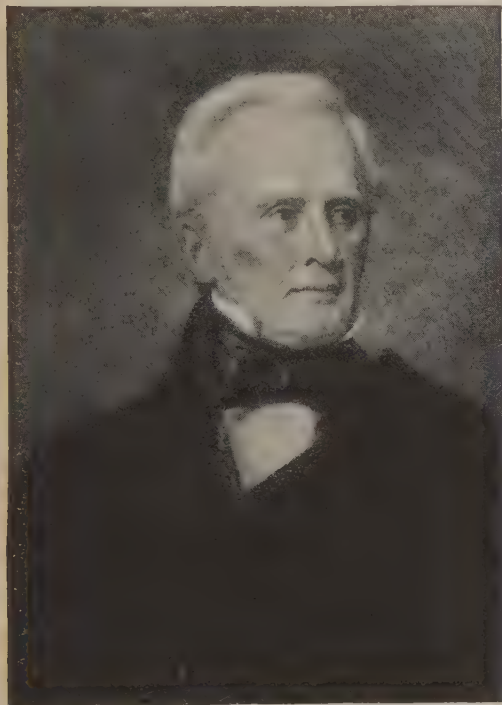
BENJAMIN SILLIMAN

The Nestor of American Science: Geologist, Chemist, and Physicist

BENJAMIN SILLIMAN was born in Trumbull, Conn., August 8, 1779, the son of a lawyer who had taken an active part in the Revolution, reaching the rank of brigadier general in the Connecticut militia. His mother traced her descent from John and Priscilla Alden. Silliman's father (1752) and grandfather (1727) were graduates of Yale, and he himself entered the college in 1792 at the age of thirteen. After taking his degree in 1796, he studied law and was admitted to the bar in 1802. Meanwhile he had been a tutor at Yale, and in 1801, when the college decided to establish a chair of chemistry and natural history, and, there being no American qualified to fill it, to select a young graduate and have him train himself for the task, he was appointed to the professorship, which he held until 1853, when he retired as professor emeritus. Silliman fitted himself in Philadelphia and in Edinburgh, where he attended medical as well as chemical lectures and came to know the leading men of science, especially those of the then rudimentary science of chemistry, at home and abroad. On his return he began at once the series of lectures that continued during his long connection with Yale.

Silliman was a man of delightful manner and agreeable delivery. His lectures were clear, fluent, and entertaining, and his demonstrations brilliant and skilfully surprising. His lectures were crowded and his influence within and without the college walls was enormous. When he opened the Lowell Institute lecture system (1839-1840) his course had to be repeated, and this occurred again and again in following years. His lectures in other cities were equally successful and did much to popularize science. By his tact and diplomatic shrewdness he added largely to the mineralogical collections of the college, obtained for it the Trumbull collection, now one of the treasures of the School of the Fine Arts at Yale, and helped form the Medical and the Sheffield Scientific Schools.

From 1818 to 1838 Silliman was the sole editor of the *American Journal of Science and Arts*, which he founded, and which for nearly a hundred years has been edited and published by members of his family with an influence on science such as "no periodical and I am not sure that any academy or university in the land has had" (Dwight). This, and his "Tour to Quebec" (1819) were very widely read and retained their popularity longer than such books usually do.



BENJAMIN SILLIMAN

As an original investigator his accomplishment was small in amount and importance, but as a teacher, lecturer and critic he has seldom been surpassed. He died on November 24, 1864.

Silliman's son, also Benjamin (1816-1885), was graduated from Yale in 1837 and became assistant to his father and later (1854-1870) succeeded him. He, too, was a popular lecturer and the author of a "First Principles of Chemistry" (1846) and a "First Principles of Physics" (1858) that had large circulations. The mineral Sillimanite is named in honor of the elder Silliman.

EDUARD SUESS

Founder of the New Geology

EDUARD SUESS, one of the greatest of physiographers, was born in London, on August 20, 1831, the son of an Austrian wool importer. When, in 1834, the great supplies of Australian wool began to come into the English market the father returned to Prague. In 1851 the son was appointed an assistant in the Imperial Museum, in Vienna, and held this post for eleven years, resigning in 1862, to devote himself to research. From 1857 to 1908 he occupied the chair of geology in the University of Vienna. For thirty years he was a member of the Austrian parliament, and from 1897 to 1911 president of the Imperial Academy of Sciences. He died in 1914.

The work of Professor Suess for the last fifty years of his life was practically identical with the advance of geology. His great study was the history of the development of the existing features of the earth's surface, and the geological principles by which these features have been brought into being. He was one of the first to take a broad scientific view of the modifications of the earth's crust. As early as 1875 his suggestive "The Origin of the Alps" opened up quite a new view of these processes. Von Zittel remarks that Suess in that work contested the upheaval of mountains and continents by forces acting vertically upward; he refuted the active participation of eruptive rocks in the origin of mountain-chains, and after a brilliant description of the most important mountain systems of the earth he demonstrated that any arrangement of those according to geometrical laws was altogether illusory. The principles of mountain building are then discussed at length, and by the exposition of various types of formation it is shown that, "while the first cause of mountain making is the secular cooling of the earth's crust, the precise form of a mountain-chain is subject to the modifying conditions introduced by those ancient and resistant crust-blocks" or old continental forms and mountain masses. In his classic "The

Face of the Earth" (3 vols., 1885-1909), the present conformation of the earth's surface is traced to earlier movements and foldings. The influences of glaciation, earthquakes, vulcanism and other factors are fully reviewed in their effect upon it.

"According to Suess," says Von Zittel, "ruptures and collapses affecting the whole thickness of the earth's crust, together with tangential folding of the upper horizons, are the forces to which the earth originally owed its surface conformation. There is no such thing as an active or passive emergence of portions of the earth's crust; in the estimation of Suess, the theory of elevation is a great error. Suess is inclined to correlate the grand physical events of the earth's history with those of the development of the organic world, and thinks it possible in this way to erect a natural and universal classification of the formations. For this purpose it is not so much the origin of new mountain systems that comes into question as the periodic recurrence of those great pelagic transgressions, *i.e.* floods, whose cause of origin until now has not been discovered." The book deals with a vast range of phenomena, treated in a most convincing way.

Professor Suess's books and papers are far too numerous to be named here, but mention should also be made of his "Palæontological Studies" and "The Ground of the City of Vienna". His studies resulted in a change in the city's water-supply, which, on his advice, was brought from the Alps a distance of over sixty miles.

ABRAHAM GOTTLÖB WERNER
The Formation of Rocks in Water

ABRAM GOTTLÖB WERNER, the scion of a family long connected with the mining industry, was born at Wehran, in Saxony, on September 25, 1749. After a period of work in the mines, he studied mineralogy in the School of Mines at Freiberg, where in 1775 he was appointed curator of the collection of minerals, and teacher. In this position, for over forty years, he wielded great influence over the hundreds of students who flocked from all parts to hear him.

Werner's service to science consisted not so much in discovery as in collating facts already known, and in presenting them in systematic order. Where hitherto ideas had been vague and confused, he insisted on the discipline of exact thought and classification; and his great merit was to introduce into the study of geology and mineralogy a coherence which had before been utterly lacking. All this was done by the spoken word. He published only one book, his "Introduction to Geognosy".

Werner classified the rock formations in five groups, which he believed to recur in series in each epoch of the geological history of the earth. This classification was based almost entirely on the mineralogical structure of the rocks, organic remains being disregarded. This omission, and the fact that his observations were restricted to a very limited area, marred his results, which were further vitiated by his exclusive devotion to the Neptunian theory. Von Zittel remarks that the Wernerian doctrine was all the more attractive as it seemed so simple. "It taught that all the rocks of the crust, like the earth's body itself, had taken origin from aqueous solutions, either as chemical or as mechanical precipitates, while volcanic lavas represented rock material that had been so precipitated, but had subsequently been melted and ejected." Hence arose one of the great historical controversies of geology, Werner's opponents, who recognized the important part taken in the construction of the earth's crust by subterranean heat, being known as Vulcanists.

Because of his vast personal influence, Werner's doctrines maintained their hold for many years, and eventually proved a hindrance to geological progress. This was especially true of his narrow Neptunist theory, and of his view of basalt as an aqueous deposit, and of volcanic outbreaks as due to the ignition of coal deposits in the crust of the earth. The importance of Werner's personal influence in introducing system and exact methods of study into the sciences of mineralogy and geognosy can hardly, however, be over-estimated. He died at Freiberg, on June 30, 1817.

ALEXANDER WINCHELL

Philosopher and Geologist

ALEXANDER WINCHELL, American geologist and palæontologist, was born on December 31, 1824, at North East, Dutchess County N. Y. Reared in a farming community, he early showed an intellectual hunger not easy to gratify. He began teaching at the age of fifteen, and, by annually returning to it for his income, and supplementing his college work by private studies, he was enabled to graduate as Bachelor of Arts at Wesleyan University in 1847. After teaching for several years, in 1854 he went to Ann Arbor, at first to a professorship of physics and civil engineering, later to one of geology, zoölogy and botany. Here he remained continuously for nearly twenty very active years, rapidly gaining the high reputation he afterwards enjoyed. In 1872 Winchell was chancellor of Syracuse University, a position he resigned two years after and assumed the chair of geology, zoölogy and botany, both in Syracuse and also in Vanderbilt University at Nashville, an institution under the control of the Methodist Church. Articles published by him on preadamites offended the authorities of Vanderbilt, and Winchell was dismissed. The University of Michigan immediately recalled him, and in the undisturbed pursuit of his work, with an activity in the classroom, or the rostrum, with the pen and in the field, the last eleven years of his life were spent there. During this period he was the promoter of two enterprises destined to exercise a strong influence on his favorite science in America. In 1888 the *American Geologist* and the Geological Society of America were founded. He died February 19, 1891.

Winchell published, in books and formal papers alone, some 8000 printed octavo pages, and geology is the subject of three-quarters of them. He viewed this science not as the companion of the other sciences but as the queen of them all. Zoölogy and botany, mineralogy, physics, and chemistry were only adjuncts, as were also to a scarcely less degree astronomy, anthropology, archæology, and languages.

To the many problems of the drift — its soil and subsoils, sanitary relations, the continental glacier — he paid much attention. His appointment as state geologist (1869) led him to a special study of the economic side of Michigan geology, and its soils and mineral fertilizers were the subject of many papers. In the stirring times of excitement over petroleum he was often consulted as an expert; he published a preliminary geological map of the state in 1854 and repeatedly revised it until in 1889 he put the finishing touches to it for the national survey. A broader outlook of geology than the study of rock and fossil, salt and soil is presented in his book, "Sketches of Creation" (1869), which of all his works still remains the one most read. "World Life" (1883) is ostensibly a compilation of the conclusions of astronomers and physicists as they bear on the evolution of the universe: in addition it is a survey of the history of worlds through an entire cycle of matter from the luminous gas of the beginning to the final catastrophe. "Evolution and its Bearing upon Theism" (1874) is a popular exposition on the descent of species couched in philosophic form without attempt to attack or defend. In the interests of geology in education he published from 1884 to 1889 "Geological Excursions", "Geological Studies", "Walks and Talks in the Geological Field", and "Shall We Teach Geology?" the first three textbooks of different grades, the last an extended plea. In other fields Winchell made valuable additions to botany, zoölogy and meteorology.

NEWTON HORACE WINCHELL

Geologist of Minnesota and of the Great Northwest

NEWTON HORACE WINCHELL, the brother of Alexander and also a geologist, was born in North East, N. Y., on December 17, 1839. In his boyhood he attended the public school at Salisbury, Conn., and at the age of sixteen taught in a district school of his native town. Two years later, in 1858, he entered the University of Michigan, where his brother was professor of geology. The next eight years were spent in studies at the university and

in school-teaching. He received the degree of Master of Arts in 1867. Like his brother, he devoted himself mainly to the science of geology, with allied interest in all branches of natural history. In Michigan he did much early work for botany, and in his later years, after his geological survey of Minnesota (1872-1900) was completed, he performed valuable services for the Minnesota Historical Society on the archæology and ethnology of this state and the Northwest. In the summer of 1874 Professor Winchell accompanied General Custer's expedition to the Black Hills, brought back valuable additions for the museum and prepared a report which contains the first geological map of the interior of the Black Hills.

He was a fellow of the American Association for the Advancement of Science and presided over its geology section in 1884. He was one of the founders of the Geological Society of America which in 1889 sprang from this, and its president in 1902. Under appointment by President Cleveland in 1887, Professor Winchell was a member of the United States Assay Commission. His geological reports received a diploma and medal at the Paris Exposition of 1889, and a medal at the World's Fair in Chicago, in 1893. He was one of the founders of the *American Geologist*, and its editor for eighteen years—an organ which greatly promoted the science of geology.

His publications include twenty-four annual reports prepared for the Geological and Natural History Survey of Minnesota and comprising some valuable papers on geology, ornithology, entomology, botany, palæontology, etc. Six huge quarto volumes of final reports of the same nature are among the most important works of Professor Winchell. His "Aborigines of Minnesota" (1911) takes up fully the question of man's antiquity and of his relation to the Ice Age. He died in Minneapolis, May 2, 1914.

KARL ALFRED VON ZITTEL
A Famous Palæontologist

KARL ALFRED VON ZITTEL was
born at Bahlingen, Baden, on Sep-

tember 25, 1839. He studied at Heidelberg and in Paris, qualified there as docent at the University, and in 1861 became an assistant in the Geological Institute of Vienna, and in 1863 professor of mineralogy at the Karlsruhe Polytechnic, whence, in 1866, he was called to the chair of palæontology at Munich. Professor Zittel was then only twenty-seven. In 1880 the science of geology was included in the duties of his professorship and in 1890 he was made trustee of the national geological collection. He was made president of the Bavarian Academy of Sciences in 1899.

Munich was the center of Zittel's labors, and from that ancient city his work has influenced the whole scientific world. The city possesses an extremely valuable collection of fossils, and to this collection Professor Zittel himself added many of its greatest treasures. He died on January 5, 1904.

Professor Zittel published many papers on geological subjects. Perhaps his most notable book is the "Handbook of Palæontology" (1876-1893). In this monumental work "almost incredible as the task may appear, Professor Zittel entered in turn upon the detailed study of each great zoological group, and made himself so thoroughly master of it and its connected literature that he could write upon it with the ripe knowledge and full authority of an expert—competent to revise the work of his predecessors. He was thus in a position to present an ordered classification of the fossil groups, and to show their affinities more clearly than had ever been done before."

Some of Professor Zittel's most valuable work was in connection with fossil sponges. The group had never been properly classified; and indeed, until the latter part of the nineteenth century, classification was almost impossible, owing to the little that was known of living sponges. He took up the study of fossil sponges by microscopic methods, and with great success. In 1899 Zittel published his admirable "History of Geology and Palæontology", in which the progress in every department of both sciences is traced from the earliest observations down to the present century.

SATURN THE MAGNIFICENT

The Story of the Gradual Discovery of Saturn's

Retinue — Three Rings and Ten Satellites

A PLANET LESS DENSE THAN WATER

FOR beauty and interest alike there is nothing in the starry heavens to compare with Saturn. This magnificent planet, unique in the solar system for its encircling rings and ten satellites, forms a spectacle which no one can ever forget who has seen it through a powerful telescope. The whole Saturnian system can be seen nearly at one view, and its perfect proportions are very wonderful.

Until the days of Herschel, Saturn was regarded as the outermost of the attendants upon the sun. For the ancients, it was the least of the seven wandering heavenly bodies, as distinguished from the fixed stars — the seven being the sun, moon, Mercury, Venus, Mars, Jupiter and Saturn. The glorious rings which surround it were invisible before the invention of the telescope. Otherwise, this astonishing diadem would surely have saved the planet from the sinister reputation it bore in the days when it was regarded, by the professors of "a sad astrology", as answerable for misfortunes and calamities of every kind and nature.

Doubtless Saturn was chosen from among the planets to bear the blame of bad luck because of its slow movement among the stars, and also because its light is less brilliant than that of any other of the seven. Seen with unaided vision, Saturn appears like a star of the first magnitude, but is excelled in brightness by Mercury, Venus, Mars and Jupiter. This dullness of aspect and lethargy of motion were supposed to impart a gloomy, phlegmatic, saturnine character to those who were so unfortunate as to come into the world when Saturn was in the ascendant.

It is a somewhat remarkable fact that in those days before telescopes this planet was thought to be the last of the solar system, because Uranus, a planet far outside the orbit of Saturn, is clearly though faintly visible by unaided sight. But although the skies had been narrowly watched for many centuries, Uranus escaped observation until its discovery by Herschel in the eighteenth century.

Saturn is so remote from the center of our system that, viewed from its orbit, the sun would appear as a star of enormous brilliancy, rather than as a disc. Saturn is nearly twice as far from the sun as is Jupiter, and receives only one-ninetieth of the heat and light we receive on earth. So remote is Saturn that from its surface none of the planets within its orbit, except Jupiter, would be seen at all, the others being merged in the dazzling brightness of the sun; and Jupiter would appear as a companion to the sun, sometimes an evening and sometimes a morning star, as Venus appears to us.

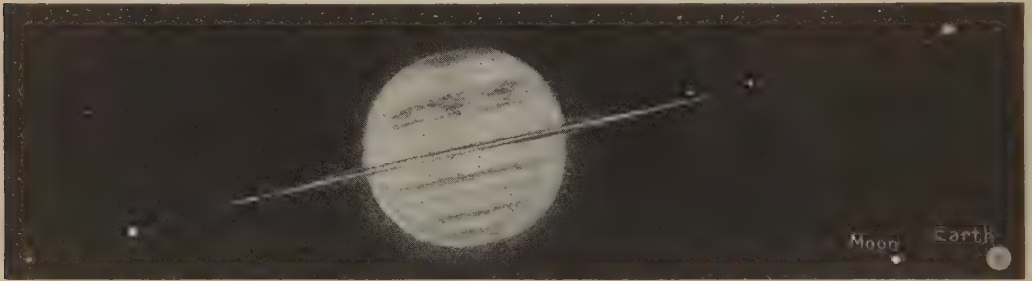
The mean distance of Saturn from the sun is 886,000,000 miles or about nine and a half times the distance of the earth from the sun. It circles round its orbit once in $29\frac{1}{2}$ years, and our earth overtakes it, and comes into line between Saturn and the sun, once in every 378 days, or 13 days over the year. The orbit of Saturn, which is inclined to the ecliptic by two and a half degrees, is slightly more eccentric than that of Jupiter, so that the distance of Saturn from the sun varies to the extent of about 99,000,000 miles.

The distance of Saturn from the earth varies, according to the position of the two

planets in their orbits, from 744,000,000 miles to 1,028,000,000 miles — a variation of distance which is not sufficient to cause any very remarkable difference in the brilliancy of Saturn. At brightest, this planet is not twice as bright as when at its greatest distance from the earth.

The globe of Saturn is greatly flattened, so that, when the planet is in such a position that the plane of its equator passes through the earth, its profile appears notably elliptical — a feature to which much of its gracefulness is due. The diameter through the poles is less by nearly one-tenth than the diameter through the equator, the former, according to Struve's measurements, being about 67,000 miles and the latter about 75,000 miles. These dimensions show the vast size of the planet, whose volume is about seven hundred and fifty times that of the earth,

tation is due the remarkably flattened shape of Saturn. Its swift revolution on its axis was first observed by Herschel in 1794 by means of cloudy markings visible on the planet which indicated a rotation period of ten hours and sixteen minutes. In 1876 Hall, of Washington, noticed a brilliant white spot on Saturn's equator, and by careful measurements found the equatorial period of rotation to be ten hours and fourteen minutes, two minutes less than the period determined by Herschel. This spot, which appeared to mark a vast eruption of glowing material from the planet's interior, lasted for several weeks, and during that time many astronomers made a close study of the planet's daily motion. In 1903 other spots appeared in higher latitudes than those previously observed, and by means of these Barnard and others found the surface to be moving in these



SATURN WITH ITS RINGS SEEN EDGEWAYS, AS THEY APPEARED IN 1920 AND 1921

The ten satellites are also shown in this drawing, and Saturn's size may be gauged from the drawings of the earth and the moon.

and about three-fifths of that of Jupiter. The superficial area of Saturn is over eighty times that of our globe. But Saturn is so distant from the earth that its vast bulk has an apparent diameter of only from fifteen to twenty seconds.

The density of Saturn is very low, much lower, indeed, than that of any other planet, and even considerably lower than the density of water. With a density of only 72 per cent that of water, it is evident that Saturn is yet far from having reached the solid condition. Like Jupiter, only in an even greater degree, Saturn is still in a more or less sun-like stage of its development and must cool for long ages to come before it can approximate to the condition of our own world. To this molten and perhaps even vaporous condition together with its extremely rapid ro-

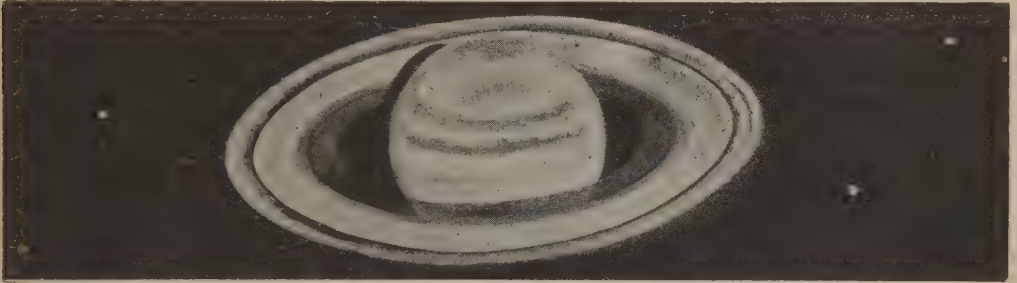
latitudes more slowly than at the equator, the period of these spots being ten hours and thirty-eight minutes. This means that a point on the equator is traveling at the tremendous linear velocity of some 23,000 miles per hour, and that there is a relative drift of 800 or 900 miles per hour between the matter at the equator and that in the higher latitudes.

The axis is inclined to the plane of the orbit by about twenty-eight degrees, giving the planet very much the same slant as the earth has in its orbit. We can hardly speak of seasons, however, in the case of Saturn, since it has no solid surface like the earth.

The visible surface of Saturn has a reflecting power exceeding even that of Jupiter, and this brilliancy is doubtless due to the fact that the reflecting surface consists of

cloud. But Saturn appears to be somewhat brighter even than white clouds, from which some have supposed that the light it sends to us is not wholly due to the reflection of sunlight, but is partially derived from the planet's own glow. This is a matter, however, upon which there is much difference of opinion, but it is probable that the glowing interior is visible to us, for Saturn has belts like those of Jupiter, only not so clearly marked, and the darker zones have the color of a red-hot mass. There is a very brilliant broad white belt round the equator, and the pole has a cap of dull green. Like Jupiter, Saturn is not so brilliant at the edge as towards the center of its disc. The spectroscope reveals a deep atmosphere which gives certain dark lines that have not been observed elsewhere except in the atmosphere of Jupiter.

largest; two others, one situated to the east, the other to the west, and on a line which does not coincide with the direction of the zodiac, seem to touch it. They are like two servants who help old Saturn on his way, and always remain at his side. With a smaller telescope the star appears lengthened, and of the shape of an olive". But continuing to watch this strange portent, month after month, Galileo was amazed to see the two attendants upon Saturn becoming smaller and smaller, until they finally disappeared altogether. He doubted the evidence of his telescope, and even the strength of his own mind. "What can I say," he wrote, "of so astonishing a metamorphosis? Are the two small stars consumed like sun-spots? Have they vanished and flown away? Has Saturn devoured his own children? Or have the glasses cheated me, and many



SATURN WITH ITS RINGS OPENED OUT TO THEIR MAXIMUM, AS THEY APPEARED IN 1915
The transparency of the inmost "crape" ring, and the shadow cast by the planet on its rings, should be noticed.

Besides its ten satellites, Saturn is surrounded by a vast swarm of small particles, compared by Clerk Maxwell to brickbats, which circulate about the planet in the form of three concentric flat rings. These rings are unique; nothing like them is known elsewhere in the universe, unless they bear some very remote analogy to the swarm of asteroids which circulate about the sun in the space between the orbits of Mars and Jupiter. It was long before the shape of these rings was made out, and longer still before their nature was understood.

They were among the first fruits of the telescope. Galileo, in 1610, examining Saturn with his new instrument, came to the conclusion that the planet had a triple form. "When I observe Saturn," he wrote to a friend, "the central star appears the

others to whom I have shown these appearances, with illusions?" Thoroughly discouraged, Galileo abandoned his observations of Saturn, and died before these strange appearances had been explained.

Others, however, watched the planet whenever it was in view, and gradually established the fact that Saturn's unique appendages underwent regular periodic changes. They appeared first as bright, straight lines stretching outwards one on each side of the elliptical disc; then, for the next seven years, these lines expanded into two luminous crescents attached to the planet like handles to a dish; and then for seven years more, the crescents became flattened down, until, as before, they were mere lines projecting from Saturn, and finally disappeared altogether. For as the planet pursues its vast orbit, slanting al-

ways in the same direction, it twice exhibits its rings, at opposite points in the orbit, edgewise to the earth; and between those two points the surfaces of the rings are exhibited, though always foreshortened, the northern surface being seen for fourteen years and more, and then, for a similar period, the southern surface.

A Dutch clock and instrument maker solves the problem of Saturn's rings

Christian Huygens, a great Dutch scientist and maker of clocks and telescopes, who was the first to bring forward in definite form the wave theory of light, and the first to apply the pendulum to the regulation of clocks, was the first to solve the problem of Saturn's rings. That is to say, he discovered that they were rings, though their constitution was unknown for long afterwards. His discovery was due not only to the greatly improved telescope which his new methods of grinding and polishing lenses had enabled him to make, but also to reasoning power of a very unusual order. Having observed the shadow thrown by the rings upon the planet's globe, and concluding that Saturn, like other planets, was probably in swift rotation upon its own axis, Huygens perceived that a very thin, broad, flat ring, entirely separate from the planet which it encircled, was the only structure that could give rise to all the various puzzling appearances observed.

Yet this hypothesis was so unprecedented, so amazing, that he hesitated to publish it. The theory was sure, in 1655, to meet with incredulity and ridicule. He therefore had recourse to a device common enough at the time, though it seems somewhat absurd now, and published an anagram or cipher which contained the mixed letters of a Latin sentence stating that Saturn "is encircled by a thin, flat ring, not cohering with the planet at any point, and inclined to the ecliptic". Further study convinced him that his theory was invulnerable, and in 1659 he gave his discovery to the world, proving it at the same time by predicting accurately the phases the rings would present in the following years.

The Italian astronomer in Paris who showed that Saturn has two distinct rings

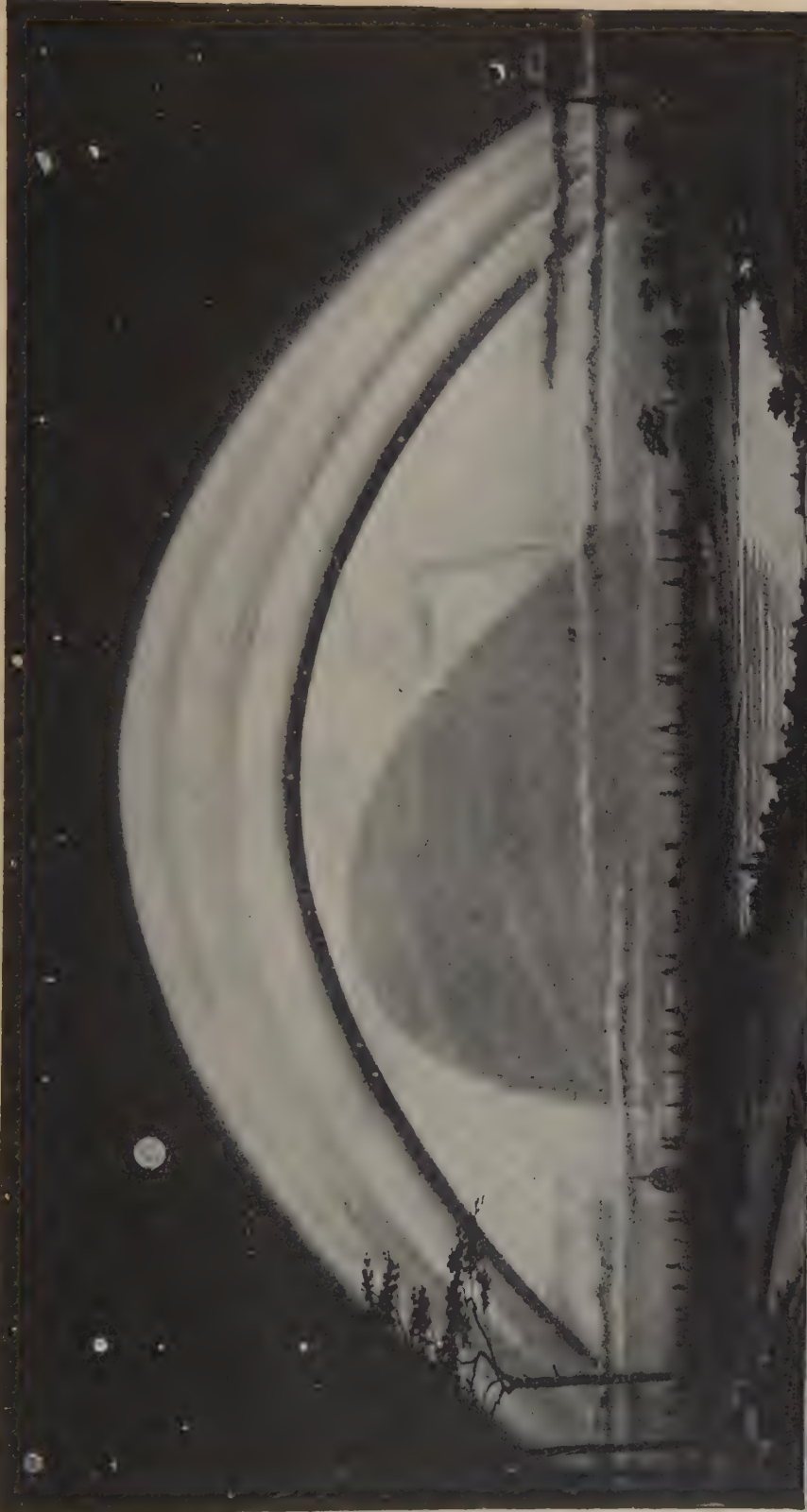
Giovanni Cassini, a learned Italian who was the first director of the Paris Observatory, had made a great reputation by his discoveries with regard to Venus, Mars and Jupiter's satellites before he made the next advance in the elucidation of Saturn's rings. He showed that there was not one ring, but two. A dark circle divides a narrower outer ring from a much broader inner ring. This dark ring was carefully studied by Cassini, Herschel and others, until it was clearly shown to be not a dark circular marking on a single ring, but a definite space between two concentric rings. This dividing space is known as "Cassini's division". The inner and the outer rings are not of equal luminosity. Cassini compared them very justly to polished and dull silver respectively.

Further examination of these rings has added to the complexity of the system. Johann Encke, a German astronomer and director of the Berlin Observatory, whose name is remembered chiefly in connection with a comet he discovered, pointed out in 1837 that the outer ring of Saturn is itself divided by another dark line, as broad but not so clearly defined as Cassini's. Encke's line can only be made out with a powerful telescope, and under favorable conditions in the position of the planet and in the terrestrial atmosphere. It is evidently not a clear division right through the outer ring, but rather a line or area in which the ring is much thinner than elsewhere.

The occasional divisions in the planet's rings that are not permanent

A year later De Vico saw two more dark lines on the inner ring, but these markings were not permanent divisions. Of these and similar discoveries Sir Robert Ball remarks that "occasionally other divisions of the ring, both inner and outer, have been recorded. It may at all events be stated that no such divisions can be regarded as permanent features. Yet their existence has been so frequently enunciated by skillful observers that it is impossible to doubt that they have been sometimes seen."

THE GORGEOUS PAGEANTRY OF THE HEAVENS AS IT MIGHT APPEAR TO A WATCHER ON SATURN



Phoebe is nearly 4 times farther off Iapetus than Iapetus.

THE SPLENDOR OF THE EVENING SKY AS IT WOULD APPEAR TO AN OBSERVER FROM THE LATITUDE OF VANCOUVER IF VANCOUVER WERE ON SATURN
The diagram below the drawing shows both the relative sizes and distances of each unit of Saturn's system as compared with that of the earth and moon.

Cassini's and Encke's discoveries were followed, in 1850, by another of a surprising nature. In that year, W. C. Bond, of Harvard, and William Dawes, an English astronomer, discovered at the same time, but independently, that Saturn has three rings, and not two as had hitherto been supposed. The third ring was observed to lie immediately within the inner of the two which were already known, and to occupy about half the space between that ring and Saturn's globe.

This "gauze" or "crape" ring, as it is often called, because of its filmy and half-transparent texture, is very dark as compared with the two rings which surround it, and had escaped observation on that account. It was not, as some were inclined to suppose at the time, a new structure, for many drawings made by earlier astronomers showed clear traces of it.

Is the gauze, or inside ring of Saturn becoming more visible?

It differs remarkably from the two outer rings, which have a solid appearance, although we know that they cannot really be solid, for the body of the planet can be seen clearly through this dusky ring. Sir Robert Ball was of opinion that the increasing facility with which the crape ring is seen is only partially due to the fact that astronomers have learned what to look for, and that there is a real change going on, by which it is becoming more substantial.

According to Barnard's measurements the equatorial radius is 38,235 miles. The diameter of the whole ring system, to the outer edge of the outer ring, is about 172,600 miles. This outer ring is about 11,100 miles in breadth; then follows Cassini's division, the dark line or area, which is about 2200 miles wide; then the middle ring, with a width of about 18,000 miles; then, without any clear separation, the crape ring, about 11,000 miles in breadth; and lastly, a space of about 5900 miles between the inner edge of the crape ring and the planet's globe. The breadth of the system of rings, from the outer edge of the outer ring to the inner edge of the crape ring, is close to 42,000 miles.

The rings all lie in one plane—that is, the plane of Saturn's equator. Their thickness probably does not exceed, according to Barnard's estimate, 30 miles. Professor Russell puts it at about 21 kilometers or 13 miles. So thin are they that when they are presented edgewise to the earth they disappear altogether.

At our passage through their plane which occurred in 1907 and in 1908 and again in 1920 and 1921, even Barnard, who was one of the keenest observers America has ever had, was unable to see even a trace of the rings with the great 40-inch telescope of the Yerkes Observatory. At both of these periods there appeared luminous knots or condensations on the rings; these condensations were of considerable thickness, and were thought by some astronomers to be due to accumulations of matter in certain sections of the rings, but, according to Barnard, the observations all showed "that these appearances were not due to actual condensations or thick places of the rings, for they were entirely invisible near and at the time when the ring was edge on to us. This proved that they were really the obscure surface of the ring illuminated by sunlight sifting through or among the individual particles composing the rings, and thus making them more or less feebly visible."

The unsolved mystery of the constitution of the rings

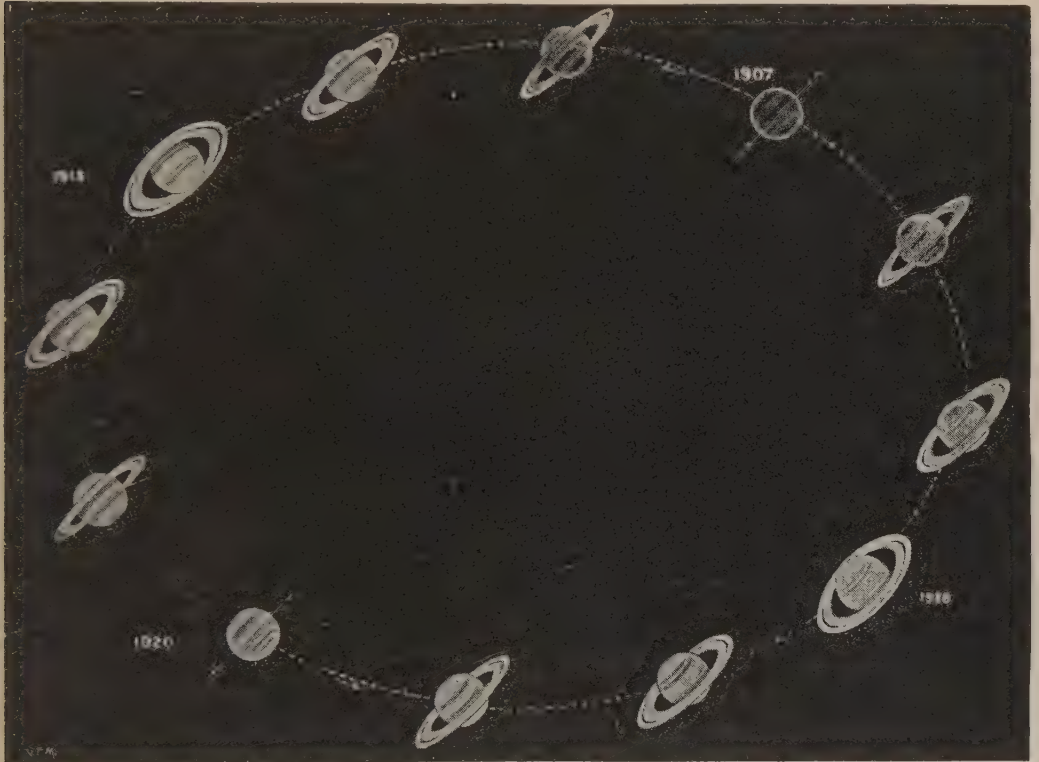
No wonder the question of the constitution of Saturn's rings became one of the greatest puzzles in astronomy. Their vast expanse, their excessive thinness, their lightness, which is such that they have been compared to immaterial light, their evident opacity, so that they throw a shadow on the planet's globe, and, above all, the absence of any other structure in the heavens wherewith they can be compared, combine to deepen their mystery.

Astronomers soon realized that solid rings were out of the question. In the first place, solid rings would be in a position of unstable equilibrium; for, as soon as the rings should shift in the least degree nearer to the planet at one point than at another, there would be a greater pull of

gravity on that point, and the rings would fall into the surface of the globe. And in the second place, even though equilibrium should be maintained, each ring would be like a stupendous arch built across the heavens; and no material could stand the crushing stress of the weight of the arch.

Nor would the centrifugal force developed by the swift rotation of the rings, however great it might be, really relieve solid structures of these dimensions from

inevitably be set up in the fluid rings, and would quickly destroy them. But the exclusion of these impossible theories leaves us with only one possibility, which has long held the universal assent of the scientific world. The rings are made up of innumerable entirely separate particles. As to the size and nature of these particles we know nothing. But whether they average the size of the motes of dust which dance in a sunbeam, or are as big as houses or as mountains, each of them is really on its



THE DIFFERENT PHASES OF SATURN'S RINGS AS SEEN FROM THE EARTH IN THE COURSE OF ITS TWENTY-NEINE AND A HALF YEARS' JOURNEY ROUND THE SUN

strains and stresses which would immediately shatter them; for centrifugal force would be greater at the outer edges of the rings than at their inner edges, while, conversely, gravitation would pull more heavily on the inner than on the outer edges. Nothing that we know could save solid rings from instant disruption.

As an alternative to solid rings, it was early suggested that they might perhaps be fluid, but mathematical investigation showed that violent wave-motions would

own account an independent satellite of Saturn. This only possible explanation of the rings of Saturn was suggested by Cassini, as early as 1715, but it received little attention until the discovery of the half-transparent crape ring, which was evidently no continuous body, whether solid or fluid. Finally in 1895 Keeler proved by spectroscopic observations that the period of rotation of different parts of the rings is precisely that required by a set of independently moving satellites, the inner

portion having a period of 5 hours, and the outermost, a period of 137 hours. The remarkable divisions between the rings still, however, remained a mystery. Why should the outer ring show a partial cleavage in Encke's division?

When meteors are all round, and are moving freely, and are doubtless continually jostling and colliding with one another what unseen force sweeps them out of the 1600-mile-wide area of Cassini's division? Here the only plausible answer was first suggested by the American astronomer Kirkwood. The reader may perhaps remember that similar clean-swept spaces are found amid the intricate tangle of the orbits of the asteroids, and that the unseen influence there at work is the gravitative power of the giant Jupiter. Any asteroid pursuing an orbit within one of these spaces would be circling round the sun in a period commensurable with the period of Jupiter in its orbit. That is to say, it would complete its circuit exactly twice in the time which Jupiter takes to revolve once round the sun, or would perform five revolutions for two of Jupiter's, or by some other simple arithmetical relation of this kind would frequently be subjected, at the same point in its orbit, to the same pull from Jupiter. The result would be that any such asteroid would be pulled out of the orbit in which it synchronized with Jupiter into another orbit in which it

would no longer be subjected to a constantly recurring pull in the same direction. A precisely similar influence has been at work upon the myriad meteors of Saturn's rings, sweeping Cassini's division wholly clear of meteors, and Encke's division perhaps only partially clear of them. In this case, however, the disturbing agency has not been another planet, but has been the major satellites of Saturn itself, or, rather, the three inner satellites, which, being the nearest to the rings of meteors, have had the greatest influence upon them. Mathematical calculations show that the satellites known as Mimas, Enceladus and Tethys revolve round Saturn in periods which are precisely commensurate with the periods of any meteors which should occupy the spaces or divisions between the rings. The three rings are due to these three satellites.

So far as is known at present, Saturn has ten satellites. The first was discovered in 1655 by Huygens; who solved the problem of the rings; Cassini found four more in the years 1671, 1672 and 1684; Herschel two more in 1789; an eighth satellite was discovered in 1848 simultaneously by W. C. Bond, of Harvard, and Lassell, an English observer; and the ninth and tenth were found in 1898 and 1904 by Professor W. H. Pickering, by photography. These last two are extremely faint objects and the true character of the tenth as a satellite has not yet been universally acknowledged.

WHERE IT NEVER RAINS



OCEANS OF SAND COVERING MAN'S AND NATURE'S HANDIWORK

RAIN AS FRIEND AND FOE

Why It Rains — How Much It Rains —
and the Queer Things that Rain Can Do

THE RED RAIN OF SUPERSTITION

RAIN consists of drops of condensed water-vapor of varying size which fall from a height through the air at a comparatively rapid rate. The fall is hastened by the running together of the fine drops in a raincloud. The combined drops have a smaller surface in proportion to their weight than the individual drops had before their combination; the air accordingly offers them less resistance, and they fall, therefore, more readily and rapidly. Though as a rule rain falls from a cloud, it occasionally, as is well known, happens that rain falls from a perfectly cloudless sky.

This takes place when the air contains too few dust-particles to provide for the condensation of the numerous little droplets that go to the making of a cloud. The moisture, therefore, instead of beginning in little droplets as a cloud, condenses at once as big drops on the scanty dust-particles, and falls at once as rain.

Rain does not necessarily reach the earth. A cloud may rain, and yet the drops of rain may evaporate before they reach the earth, and no doubt this happens more often than is commonly supposed. The condensation that results in rain is quite simple in its general principles. The warmer the air, the more water-vapor it can hold. When, accordingly, warm air containing a certain quantity of water-vapor is cooled, it becomes, at a certain point — called the "dew-point" — incapable of holding all the water-vapor it could hold when warmer, and the vapor accordingly condenses on any solid, cool particles it can find. A cooling by any means of warm, vapor-laden air is the ordinary origin of rain.

This cooling may be effected in various ways: by a cool breeze, or by a cold hill, or by expansion — as when a breeze blows uphill. In mountainous districts both the last two conditions are found, and hence in such there is usually a large rainfall.

The cloud that so often attaches itself to the summit of a high peak is not a cloud that has caught there, but that has been formed there; and often, as the wind blows over a snowy peak, a cloud streaming from the peak like a pennant demonstrates the condensation of the water-vapor it contains. The condensation of the escaping steam of a locomotive, and of the breath on a cold day, are illustrations of the same process on a small scale. All that is required is water-vapor, sufficient cold to condense it, and nuclei, such as dust-particles, to serve as centers of condensation.

From what we have already said, it is evident that the distribution of rain must depend largely on the physical features of the land. In a general way, the following rules may be laid down.

Towards the equator the rainfall increases, and towards the poles it diminishes. The reason of this is that the heat of the tropical zones evaporates the greatest quantity of water and the vapor thus formed is readily precipitated.

Other things being equal, there is more rain near the sea than inland. First because a wind from the sea is likely to contain a quantity of water-vapor; and second, because the land and the sea are often of different temperatures, and thus a warm, moist wind off one may be condensed by the other.

Other things being equal, the rainfall increases with the height above sea level, provided always a height above ordinary cloud-level is not attained. This is due to the action of mountains in condensing water-vapor, as we have already explained.

The average rainfall of the plains of Europe is 22.6 inches per year, whereas in mountainous districts it is over 50 inches. In the valley of the Rhine, the average rainfall is 22 or 23 inches; in the Vosges mountains it reaches 47 inches in certain districts. At Arles, it is 17.7 inches, while

The rainiest district in the world is probably the lower slopes of the Himalayas. Here all the physical conditions conduce to a heavy rainfall. We have the steaming water in the great Indian Ocean, and the barrier of the Himalayas, which intercepts the wet monsoons and condenses the moisture they contain. Even on the delta of the Indus the rainfall is considerable, but it is when the moist currents reach the hills that the really heavy rains begin. At Ulu Selangor, in the Malay Peninsula, there is an average annual rainfall of 323



TABLE MOUNTAIN, NEAR CAPE TOWN, COVERED BY ITS TABLECLOTH OF CLOUD

at Joyeuse, in the mountains sixty miles away, it averages 51. At Geneva, it is 32 inches; at the St. Bernard Hospice, 79.

In the United States the annual rainfall along the Atlantic Coast varies from 30 to 80 inches, the mean annual precipitation in New York State being 39.3 inches; along the western slope of the Continental Divide the precipitation is abundant, reaching in some localities 135 inches a year, but in the interior it is generally smaller, being in a number of states less than 15 inches a year.

At Mahabuleshvar, on the western slope of the Ghauts, it is 275 inches; while at Cherrapunji, on the Khasi Hills, 200 miles north of the Bay of Bengal, it reaches almost 500 inches. Recently during the first ten months of the year, no less than 560 inches fell at Cherrapunji, nor is this a record, for in 1861, 805 inches were registered, and of that total 366 inches fell in July. Sixty-seven feet of rain in a single year! As much in that month of July as falls at Leh, on the other side of the Himalayas, in 100 years!

THE CLOUD-BANNER OF THE MATTERHORN



A CLOUD CONDENSING ON THE COLD SIDE OF THE MATTERHORN



A CLOSE VIEW OF THE MIST-LIKE CLOUD ON THE SLOPES OF THE MATTERHORN

In this place of truly amazing wetness 40 inches of rain have fallen in 24 hours; this equals 224 gallons or nearly one ton of water on each square yard of surface. There are places in Europe where there are occasionally terrific rains. At Joyeuse, in France, 31.17 inches fell in 22 hours; at Geneva, 30 inches in 24 hours; and at Gibraltar, 33 inches in 24 hours. But the heaviest downpour on record occurred in November, 1911, at Porto Bello, Panama, when 2.48 inches fell in 5 minutes. Fortunately for Panama such a rainfall is not typical of its climate.

The movement backward and forward of this great girdle of clouds makes a regular alternation of wet and dry seasons in the tropics; and the rainy season is in summer, so that there are clouds and rain just when they are most wanted. In the immediate neighborhood of the equator there are two dry and two wet seasons. How much rain falls on the tropical seas cannot be calculated, but the amount must be very large. Occasionally the rainfall is so heavy that sailors are able to collect a supply of fresh water from the surface of the ocean.



A RAIN-WROUGHT LANDSLIDE OF BLUE CLAY ON THE HAMPSHIRE COAST, ENGLAND

The heavy rainfalls in the tropics are not due to condensation of moisture by mountain ranges so much as to the condensing effect of cold winds pouring in from cooler regions. The line of meeting moves north and south with the movement of the sun. When the sun is north of the equator the zone of clouds is also north of the equator, and when the sun is south of the equator the zone of clouds is found in the southern hemisphere. Reclus says: "It is undoubtedly visible from the nearest heavenly bodies, and must resemble those whitish bands which our telescopes discover on the planet Jupiter."

In the temperate zones there are no clearly defined dry and wet seasons, and the rainfall is much more irregular, depending on numerous variable factors. On the Southern Russian steppes and in the Hungarian highlands the heaviest rainfall is in summer, while in Spain and Portugal the heaviest rainfall is in autumn and winter.

In certain regions of the globe there is almost no rain. Very rarely does it rain in the districts south and east of the Caspian Sea, on the African Karoo, in southern Australia, in the Arctic regions, in the regions south of latitude 60°, and in

MOUNTAINS WHERE THERE IS "NO RAIN, NOR ANY DEW, NEITHER FIELDS OF OFFERING"



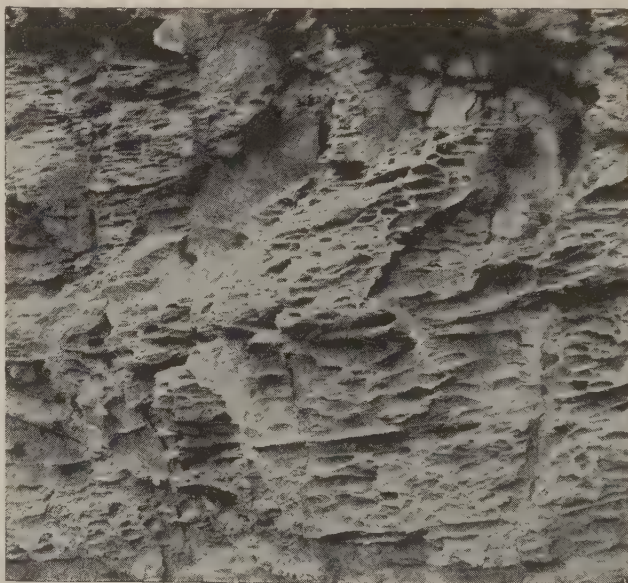
A RAINLESS REGION OF AFRICA, WHERE THE SANDS OF THE DESERT HAVE OBLITERATED THE WORKS OF MAN EXECUTED UNDER A KINDLIER CLIMATE

the canyon country of Arizona. And a strip of the western slopes of the Andes, extending southwards through Peru and part of Chile from latitude 5° S. to about latitude 35° S. is altogether rainless, all the rain being retained by the mountains that rise to the east. In Peru "the appearance of a cloud is a real event, and the whole population assembles to contemplate this unaccustomed spectacle." Rainless, too, is a belt of land, about 10° in breadth, which, extending across Africa, including the Sahara and Libyan deserts, crosses the north of Arabia into Persia to terminate near the western border of Afghanistan. And still a third rainless region includes eastern Turkestan, with the Desert of Gobi.

Where there is no rain, the contours of mountain and plain have a characteristic monotonous appearance. There are no glens, valleys and streams — only flat plains and level plateaus. Where there is no rain there is also no vegetation except lichen. Dry, dusty desolation prevails throughout the length and breadth of the rainless land.

Where the rainfall is small it is of the utmost importance. On the African Karoo when the rains fail all the vegetation of the Karoo perishes, and sheep and other animals die of lack of food. And when the rains do come the sudden response of vegetation to the moisture is like a miracle. When there is a dry season and a wet season, the wet season is like a resurrection. Reclus describes how in the dry season the soil of the llanos of Colombia dries up: "The watercourses become exhausted; the lakes change into pools

and then into sloughs, in the mud of which crocodiles and serpents delight to wallow; the clayey ground shrinks and cracks, the plants wither and are torn to shreds by the wind, the cattle, driven by hunger and thirst, take refuge in the neighborhood of the great river, and multitudes of their skeletons lie bleaching on the plains. . . . All at once the storms of the rainy season inundate the soil, multitudes of plants shoot out from the dust, and the yellow expanse is transformed into a flowery meadow." It is little wonder that in some savage tribes the rain-doctor is a personage of some importance.



HONEYCOMB WEATHERING AT PORTSCATHO, CORNWALL

It has often been maintained that trees bring rain and that the felling of forests decreases the rainfall. There is no doubt at all that the deforestation diminishes the permeability of soil, and diminishes, too, its capacity for catching and holding water. Trees both collect water round their roots and hinder its evaporation by means

of their foliage. Where trees overshadow a road is usually the part of the road that takes longest to dry.

Where trees overshadow a spring they conserve its water for the dry seasons. There is no doubt that in these ways trees collect and conserve rain, but whether they actually attract rain is rather a moot question. On the whole, it seems probable that trees do in some way attract the rain. "It must not be forgotten," writes Dr. Robert Brown, "that the slightest difference in the temperature of the soil, especially of the hills, over which a vapor-laden cloud is sailing, may determine whether its moisture will be condensed

ON THE BORDERLAND OF DESOLATION



AN ARAB OUTPOST KEEPING WATCH AMONG THE SAND DUNES OF TRIPOLI

and precipitated, or whether the misty vapor will float away without the thirsty earth obtaining the benefit of its contents, here more grudgingly bestowed than in the cooler regions near the poles." Certainly trees do not retain heat, and they are usually cooler than the soil.

Whether by favoring condensation, whether through the high electrical tension of the tops and tips, there seems a fair amount of evidence that forests directly attract rain, and that deforestation leads to drought. The cutting down of trees in St. Helena was followed by a decrease in



AN EARTH-PILLAR IN THE RHONE VALLEY

the rainfall; while a replanting of trees was followed, in turn, by an increased rainfall. In Upper Egypt, destruction of trees along the banks of the Nile was followed by drought, while in Lower Egypt the planting of trees has been followed by an increased rainfall. No universal rule, however, can be drawn from these instances, for in the United States deforestation has not caused any measurable change in the quantity of rainfall, as was shown by a careful statistical study made by Professor Willis L. Moor, former director of the U. S. Weather Bureau.

One of the great dangers of drought is liability of field and forest to conflagrations. After weeks of dry weather, grass and shrub and tree are like tinder, ready to catch fire, and a very small spark may kindle a destructive fire. Sometimes even the friction of two branches against each other may suffice to kindle a flame. Forest and prairie fires sometimes spread for many miles. In 1923 whole towns were wiped out in southern California.

In various districts there are occasional showers of red rain — blood-showers — much disturbing the hearts of the superstitious. Such red rain is most common over the Cape Verde Islands and the countries bordering the Mediterranean, but sometimes it has been seen as far north as Sweden. It consists of rain mixed with a quantity of red dust, in most cases torn by the wind from the deserts of the north of Africa. When such rain evaporates a residue of fine red dust is left behind.

Rain does not work only by the intermediation of a stream or river; as rain it plays a direct and important part in molding the face of the earth. Its action is partly chemical and partly mechanical.

First as to its chemical action. Rain is never quite pure water. In the atmosphere it absorbs the atmospheric gases — oxygen, nitrogen and carbon dioxide. The gases are found to be absorbed in the following average proportions: nitrogen, 64.47; oxygen, 33.76; carbon dioxide, 1.77. It will be noticed that the absorbed gases are not found in the same proportion as in the atmosphere, and that the carbon dioxide occurs in proportions thirty to forty times greater than in the atmosphere. Besides these natural atmospheric gases, rain also absorbs in its passage through the atmosphere a certain amount of nitric acid, sulphuric acid and salts. Further, it carries down with it germs and dust. As soon as it touches the earth it adds to its chemical contents.

Rain, accordingly, contains various more or less active chemical substances, and has a varied chemical action on the rocks and soil on which it falls. Owing to its oxygen it oxidizes or rusts various minerals, such as iron, which it passes over.

Owing to the organic matter it contains it deoxidizes other minerals such as gypsum. And, owing to the carbonic acid it contains, it dissolves limestone and marble, carbonate of magnesia and other minerals. The so-called "pipes" and "swallow holes" found in limestone rock are funnel-shaped cavities corroded in the limestone by rain. If there be no soil on the surface to fill up these holes, they deepen, and may eventually become caverns.

The Karst district of Dalmatia is honey-combed with these holes, which are locally known as "doliniens" or "dolinas". Some of them are deep, the deepest 525 feet, some shallow. At the bottom is found a red earth, which is the insoluble iron oxide residue of the limestone. In northern Bohemia and Saxony hollows 3 to 30 feet deep, known as "karren" or "sehratten", are found, and these doubtless are also formed by rain eroding the limestone rock.

Even granite is rotted by water, so that it becomes loose and can be dug into with a spade, and is broken up with clay and sand. In the District of Columbia granite has been found decomposed to a depth of 80 to 100 feet. At Carclaze, near St. Austell, in Cornwall, Wales, huge pits, as big as a skyscraper, have been dug into the granite in search of tin and china clay.

In some cases when rain is absorbed by rock, the latter forms a chemical compound with the water, and undergoes the change known as "hydration". Anhydrite, for instance, is converted into gypsum, and increases in bulk at the same time about 33 per cent.

The mechanical action of rain is quite obvious. Every heavy shower of rain scours and scars the roads and paths with its runnels; and when the rain comes down "in sheets" it carries away the soil as effectively as a river. Where there are trees and vegetation to shield the soil and to hold it together, the rain may fail to remove much of it, but where the soil is unprotected it may be quickly carried away. The destruction of forests, accordingly, even when it diminishes rainfall, increases the destructive effect of rain, and many parts of Syria, Greece, Asia Minor, Africa and Spain have first been denuded

of trees by men, and then of soil by the rain. "If," wrote Reclus, "some modern Attila, traversing the Alps, made it his business to desolate these valleys for ever, the first thing he should do would be to encourage the inhabitants in their senseless work of destruction."

In some cases torrential rain produces floods of mud; a terrible instance of this kind occurred near Vesuvius in September, 1911.

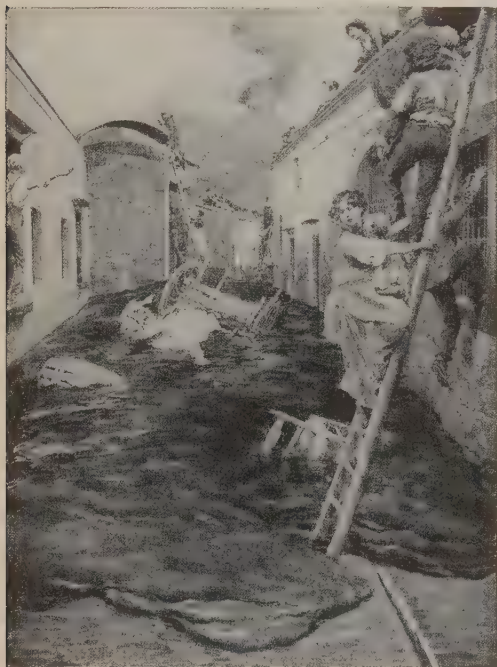


THE RAIN'S ACTION ON ROCKS — THE GENDARME
NEAR THE ORTLER, TYROL

"The torrential rains which fell caused a huge volume of mud and lava to flow down the sides of the mountain, and this, dividing into several branches, swept over the entire country-side, destroying everything in its path. The town of Resina was completely engulfed in it, and the mud gradually reached the height of the first-floor windows of the houses. To describe the horror of the scenes that ensued one would be obliged to have recourse to the most awesome incidents in Dante's 'Inferno'. The floating corpses of people who had been overtaken by the terrible

flood presented a dreadful spectacle on the surface of the lava. Farming utensils and furniture, together with cows, horses, and various other domestic animals, were also caught up and borne along by the stream. The district of Miglio de Oro, one of the most enchanting parts of the commune of Resina, has been flooded with mud and totally ruined. The onrush of the lava was such that many houses were swept away bodily. . . .

"The scene at Resina is described as dreadful. The impetuous torrent rushed



ESCAPING FROM THE VESUVIAN MUD-FLOOD

down the mountain-side, and burst with great force against the walls of the houses. The doors crashed in, and the thick stream of lava flooded the lower floors, ruining the interiors of the dwellings. In many cases the mud inside the houses flooded the stairs and the upper floors, breaking practically all the windows in the town. Many persons, particularly women and children, were so terrified by the unusual sight that they had not even sufficient energy left to save themselves, and they were consequently drowned by the awful torrent that still came pouring down the mountain-side. Some time afterwards

many bodies were recovered, the faces in every case bearing an expression of the utmost horror. Vivid flashes of lightning and peals of thunder added to the terror of the inhabitants."

A similar mud-stream occurred in the Philippine Islands in 1876. Torrents of rain descended on the volcano Mayon, and a deluge of mud, cinders and ashes broke down bridges, blocked roads, destroyed villages and wrecked over six thousand houses.

In other cases rain destroys, not by causing deluges of mud such as we have described, but by producing landslides, in which rain plays a triple part—it disintegrates the soil, it loosens its attachment to underlying rock and it adds immensely to its weight. Frost, too, takes part in the process, by causing a general expansion of the water in the crevices and pores of rocks and soil, and many severe landslides take place during or after frosty weather. The numerous landslides on the coast attributed to the sea are often mainly due to the rain—the sea merely giving the finishing touch to the loosened mass. Much, too, that is attributed to rivers is really due to rain. We are accustomed to think of rivers carving out the broad valleys, but probably half the work is done by rain, tumbling the banks into the river. All that rivers can do without rain is seen in the rainless canyon country of Arizona, where the rivers make not valleys and glens but cut steep gorges with perpendicular banks. If the canyon country should come to have a rainfall like Cherrapunji its contours would very soon be completely altered.

Most of the great landslides occur among mountains. In 1806, after heavy rains, a huge mass of pudding-stone broke loose from the Rossberg, a mountain in Switzerland, near the Rigi, and in a few minutes the village of Goldau and three adjacent hamlets, together with 433 natives and 24 visitors, were buried 100 to 200 feet deep. So violent and rapid was the movement that the friction of the rocks striking and rubbing against each other gave rise to flames which "broke in fiery jets from the half-opened mountain". The lake of Lowerz was partly filled up, and the pre-

cipitation into it of such a mass of debris gave rise to waves that swept away all the houses on its banks. Even birds flying in the air were killed. It is estimated that the falling mass contained more than 54 million cubic yards, and measured $2\frac{1}{2}$ miles long by 350 yards wide and 35 yards thick. A landslide in 1881 at the Tschingel Alp had almost as disastrous consequences, destroying the village of Elm and most of its inhabitants. This fallen mass contained enough stone to build a city. In 1618 a slide occurred at Monte Conto which buried the town of Plurs, with 2430 inhabitants; and though attempts were made to dig it out no trace of it could be found. In some cases landslides rush down with the speed of an ava-

pillar is capped with a boulder. In the Sierra Nevada some pillars reach a height of 700 feet. They are simply hardened columns of clay, which, protected by their capping of stone, have resisted the eroding power of the rain, while all the clay round about has been washed away. If the capping stone falls off, the rain soon melts the pillar away, or cuts it down until another stone protects it again from further erosion.

Mount Roraima, in British Guiana, a mountain rising 8580 feet and consisting of soft sandstone capped with conglomerate, is thought by some to be really a gigantic earth-pillar, its soft sandstone having been protected from the rain by its hard conglomerate capping. Other cu-



RESIDUAL BLOCKS OF WEATHERED GABBRO ON THE CROUSA DOWNS, ST. KEVERN, ENGLAND

lanche, and propel compressed air before them with such force that villages are blown away.

But rain does not always act in such a dramatic and tragic fashion; sometimes its work is merely fantastic, like the tall pinacles of stony clay known as earth-pillars. They occur in the Tyrol, in the Himalayas, in the Sierra Nevada, at Fochabers, in Scotland, and in other parts of the world. Very characteristic and remarkable are the earth-pillars which occur in a glen on the Rittnerhorn, in the Italian Tyrol. The glen has been cut out of clay by a mountain stream, and on either side it is fringed with these earth-pillars, from 8 to 30 feet high, and "crowded like tombs in an overfull churchyard". Almost every

rious achievements of the rain are seen in the "Stone Rivers" of the Falkland Islands. Most of the valleys in the East Island are filled with large, angular blocks of quartzite covered with a thin, extremely hard white lichen, which looks like a coating of ice. "Far down below, under the stones, one can hear the stream of water gurgling." Exactly how these Stone Rivers are made is not known, but they are certainly the product of the disintegrating and denuding action of rain.

Other bizarre and rococo results of rain are seen in the remarkable piles of stones found here and there all over the world, and usually known locally by such names as "Devil's Castle", "Lover's Seat", "Grandfather's Chair", etc.

HUNGRY RAIDERS OF HUMAN BLOOD



THE DEVELOPMENT AND FISSION OF THE MALARIA PARASITE IN HUMAN BLOOD



THE FERTILIZATION AND DEVELOPMENT OF MALARIA PARASITES WITHIN THE MOSQUITO

The upper picture shows the form in which the malaria parasites, present in large numbers in the saliva of the mosquito, enter a minute capillary of the blood through the wound made by the bite. One can be seen penetrating a red blood corpuscle, and several successive stages of the parasite's development and multiplication by fission are shown, the free spores thus formed being capable of infecting fresh corpuscles. The sexual types of the organism, shown in the bottom left-hand corner, will pass into the mosquito through the human blood, upon which the mosquito feeds. These sexual varieties go through the series shown in the lower picture in the body of the mosquito, finally developing into the spore form which infects the human species through the wound, as shown above.

THE OMNIPRESENT PARASITE

The New World of Internal Life, Hitherto
Invisible, Revealed by the Microscope

THE PLACE OF PARASITES IN DISEASE

STRICTLY speaking, it is not so easy to define parasitism, for any definition will be almost certain unintentionally to include, for instance, man as a parasite upon the cow, whose milk we consume. All forms of life are so interdependent that, from one point of view, anything specially to be called parasitism can scarcely be distinguished at all. We must also exclude symbiosis, as illustrated in the lichen, where two forms of life are bound up in a mutually advantageous partnership. We must exclude saprophytism, the case of those many vegetable organisms which live upon *dead* organic matter or upon organic products. In the strict definition, man would be saprophytic rather than parasitic upon the cow, for milk is not itself alive. We must confine parasitism to the cases where one living creature lives upon and derives its food from the tissues of another creature, which is called its host.

It is usual to include in the concept of parasitism the idea of injury to the host, but that is not absolutely necessary. No doubt the incidental injury to the host is very important, and, indeed, matters everything to ourselves, who are liable to be the hosts of so many unwelcome and even deadly guests. There are plenty of cases of parasitism where it is impossible to say that the host suffers any injury, but the parasite is definitely a parasite, none the less. Bacteriologists have identified some thirty different forms of bacteria among what they quaintly call the "flora" of the mouth, but most of these are entirely innocent, no doubt. Similarly, the "flora" of the bowel includes many forms which are

harmless. But if they depend upon the host for their sustenance without making any returns beneficial to the host, they must be considered parasites even though they inflict no apparent injury. A parasite exacts something for nothing.

It may fairly be said that parasitism is a universal fact of the living world. This was long ago stated in the familiar lines —

Great fleas have little fleas upon their backs to
bite 'em,
And little fleas have lesser fleas, and so *ad infinitum*.

We shall soon see that this is far truer than anyone could guess until the perfection of modern microscopy. But these lines may serve to remind us that parasitism, in its more familiar form, means the presence of smaller organisms upon the exterior of a larger one, as in the case of the flea. We now know, however, that parasites may just as well thrive inside the body of their host. The convenient distinction may thus be made between ecto-parasites and endo-parasites, which live respectively without and within the body of their host.

Everyone is familiar nowadays with the bacteria, many of which are parasitic. Their dimensions may be very small, as in the case of many round forms, called cocci, which may have a diameter of as little as one *micron*, which is the twenty-five-thousandth part of an inch. A millimeter is about one-twenty-fifth of an inch; but so minute are the dimensions of these creatures that we require to use a new unit, called the micron, which is the thousandth part of a millimeter.

It may very naturally be supposed that such dimensions would be the very limit of living forms, and until lately it was so supposed. But recently the lines of the versifier have been justified. We now have good reason to believe that still more minute organisms, the dimensions of which can be expressed only in millionths of an inch, are to be found parasitic upon the bacteria.

When we study the limits of microscopic vision, which depend upon the wavelength of light, so that, even by oblique illumination with light having a wavelength of, for instance, one-40,000th of an inch, we can see objects of at least only half that dimension, it will be realized that these minute organisms are ultra-microscopic. Their existence may be demonstrable by their effects, and their properties may be definable, but, except in indirect and partial fashion, the eye of man cannot hope ever to see them.

Parasites so small that the microscope cannot detect them

This discovery of ultra-microscopic forms of life is so important that we must briefly refer to it further before we proceed with the subject of which they are only the most extreme illustration. In due course we shall learn that there are several diseases in which no one can doubt that a parasite is involved, but no such parasite can be found. Infectious material may be searched by every modern refinement of technique and staining, but nothing can be seen in it. Students have long suspected the reason to be that the parasite in these cases was ultra-microscopic, a suspicion which we must now accept as verified. It raises many new problems, for evidently we are deprived of our right hand when the microscope itself fails us.

It is quite likely that the unknown parasite which produces foot-and-mouth disease in cattle belongs to this category of the ultra-microscopic. We may just remind ourselves, however, that it is only in recent years that the bacteriologists have been at all justified in the assumption that what they cannot see is invisible, and in some instances, no doubt, they will be able to disprove their own suspicion.

So much depends on technique. If we follow the proper procedure we can always readily find the tubercle bacillus, when it is present, but that procedure involves treating the bacillus with something which enables it to hold a certain dye or stain, and then applying the stain in question. Until we go through this procedure in just the right way, we may look for years and find nothing, as Koch did in this very case before he succeeded.

The progress of the discovery of organisms too small for sight

Another instance is furnished by the parasite of syphilis, which was discovered by Schaudin in 1905 and which is really quite long, but is so exceedingly slender and transparent that it escaped all search for decades. Nevertheless, if we keep these warning instances in mind, and remember how thoroughly bacteriologists have taken them to heart, we must still agree that really ultra-microscopic organisms do exist.

Those hitherto "discovered", if that word may be used, are parasitic; but it remains to be seen whether similar organisms may not exist which are non-parasitic, and which perhaps lay the chemical foundations for all higher forms of life. However that may be, these recent discoveries in parasitism have required us to modify our ideas on the very interesting question—how small may a living organism be? It is now clear that life may be manifested in individual units which are so small that the number of actual molecules in them begins to be enumerable. And as our knowledge in this direction extends, the physico-chemical conceptions of life which satisfied most men of science in the nineteenth century seem to become less tenable than ever. But this is a field of inquiry so novel that we can as yet do no more than recognize its existence.

Having learned how general a fact parasitism is, extending from such large creatures as, say, the tapeworm, down to forms which no microscope can reveal, we should ask ourselves why this should be so. The answer is that parasitism solves so easily the chemical problems which face every living creature. In order to live, protoplasm re-

quires a constant supply of the particular elements and certain of the compounds of which it is made.

The parasite's aim — to live on ready-made food

These quite indispensable materials may, of course, be laboriously and honestly gathered, one by one, from their various natural sources. The process will tend to be a slow one, and at any time the sources may not be available. Obviously, there is a short cut, and that is to avail oneself of the collection and elaboration which some other living creature has already made. This convenient arrangement, with no disadvantages at all, we see in the case of many external parasites, such as the blood-sucking insects, which have lately become of such enormous importance to our understanding of disease, in consequence of the fact that they themselves have parasites, which they hand on to the creature they bite. The flea or tsetse-fly or mosquito lives conveniently by helping itself to a ready-made fluid, rich in nourishment, which the life of another creature has elaborated for its own purposes. Other parasites do better still, as in the case of that admirable product of natural selection, the tapeworm. This creature, which we may take as typical of many, benefits by its parasitism to the greatest possible extent. The body of its host provides it with warmth and shelter. It has no need of locomotion, nor of any kind of exposure. The flea or mosquito requires to digest the blood of its victim, but the tapeworm does much better. It takes up its abode in the bowel, just where the food reaches its fully-digested form, and it thus has available a plentiful supply of pre-digested food, which comes to it, and demands no effort whatever but that of receiving it.

The degeneracy of parasite always in proportion to its dependence

A universal rule of parasitism is that the degeneracy of the parasite is in proportion to its dependence. Thus, in physical terms, at any rate, there is little degeneracy to be observed in the mosquito, which has to fly, to bite, to digest. But the tape-

worm has to do practically nothing, and so all its organs degenerate, except those of reproduction. It loses its means of locomotion, its senses, its power of digestion, and so forth; these are not called for; it has chosen an easier way of life, and they disappear accordingly. This can scarcely be called a case of the struggle for existence. The tapeworm produces no poisons, and the body makes no attack upon it.

The struggle between poisonous parasites and substances that defend the body

But with yet other parasites the case is very different. These are typified by the parasite of malaria, which is an animal, and that of consumption, which is a plant. Here the struggle for existence is genuinely illustrated. Originally, of course, we are to imagine no animosity on the part of the parasite towards its host. It is merely trying to avail itself of an abundant source of nourishment. In the course of doing so, however, it produces substances, commonly called toxins or poisons, which happen to be noxious to its host. The host therefore tries to protect itself, by producing substances which will kill the parasite; and thus a struggle for life begins. It is this struggle which we see illustrated only too often, and which we call disease. The details vary widely in different cases, but this is the essence of nearly all of them.

Parasitism being the general fact of the living world that it is, we must be prepared to find that animals and vegetables alike have parasites, and that these may themselves be animal or vegetable. At one moment you may be spraying your throat with an antiseptic, and at the next your rose-bushes; and in each case your object is to kill parasites. In the case of mankind the parasites first known were, of course, the biting insects. Then we discovered other animal forms, living within the bowel, though some may live, during part of their life-cycle, in other organs, such as the muscles and the liver. Much later, thanks to the chemical study of fermentation and the improvement of the microscope, we found a variety of vegetable parasites, far commoner and more important than any known animal parasite, internal or external.

Animal parasites which, like vegetable parasites, are dangerous to the body

While the greater number of diseases could be accredited to these minute plants, only one case was known where a minute animal played a similar part. This was the case of the parasite of malaria, discovered by Laveran, a French army surgeon, in the year 1880.

Within recent years, however, the number of these minute animal parasites has been greatly augmented. Syphilis, for instance, is due to one, so that they can already claim two of the most important of all diseases. A terrible form of dysentery is also due to an animal parasite, of the class of amoebæ, known as the *amoeba dysenteriae*. Still later, a new genus of animals has had to be recognized as parasites, causing the various forms of disease called "trypanosomiasis", after the parasite, called "the trypanosoma". But there are many different forms of trypanosoma, whose normal habitat is the blood of many creatures besides man, and that which causes sleeping-sickness in man is only the most important.

Parasitism a lazy acceptance of "most life at least trouble"

We are clearly to understand, then, that parasitism is not only a relation between an animal on the one hand and a vegetable on the other. It occurs in all possible ways; and we know no form of life, animal or vegetable, which is wholly immune from parasitism. We think of many insects as parasites, and so they are, but the insects are themselves subject to parasites, like the lamentable infections which attack bees; and even parasitic insects like the malarial mosquito are themselves the hosts of the animal parasite with which they later infect man. And in the blood of worms or fishes we find parasites in just the same way. Similarly, it may be said that almost every form of life can be persuaded to become parasitic under suitable circumstances; it will always be glad to accept the most life at the least trouble.

Every parasitic species has taken to this mode of existence somehow. If we could

trace its line far enough upwards, we should find non-parasitic ancestors at the head of it. But to this rule—that species in general can be persuaded, only too readily, into parasitism under suitable circumstances—the green plants, taken as a whole, are the honorable exception. In virtue of their chlorophyll, as we may remember, they have direct access to an endless source of energy in the form of the sunlight which pours down upon them; and under favorable conditions their growth merely becomes more luxuriant and abundant.

Green plants which live as parasites at the expense of their fellows

But even here there are certain striking exceptions. No green plant is parasitic upon animals. We have quite enough to fear from the vegetable world, but only from the fungi. Certain green plants are, however, more or less wholly parasitic upon other plants. The general rule is that they germinate in the ground, often with some honest roots of their own, by which they obtain the salts in the soil-water, but also with a root in the underground portion of their host. Several plants, such as the eye-bright, have small green leaves of their own, so that they are only partly parasitic. Others, such as the broom-rapes, have really lost all their chlorophyll, and are wholly parasitic but for the fact that they have some roots of their own. The dodder, after twining round the stem of its host, into which it sends sucker-like branches, dies at its own root, and thus ceases to have any connection with the ground. The sucker-like branches, which are modified roots, serve all its purposes at the expense of its host.

Parasite specimens of plant and animal life up to the man who "sponges"

The mistletoe is in part a parasite, but by no means wholly so, for it has green leaves, and therefore is able in large measure to feed itself. The ivy, though often thought of as parasitic, is not so at all, having green leaves and true roots of its own, and merely using trees, as it would use a wall, for purposes of support.

Among flowering plants, perhaps the most striking and thoroughgoing parasite is the rafflesia, discovered by Sir Stamford Raffles in Java, nearly a century ago. It has no foliage leaves at all, and grows on the trailing stems of a vine, producing a huge flower some two or three feet across, at the top of a short root which penetrates the stem of the vine.

The recently discovered microscopic forms the most important of animal parasites

By far the most important animal parasites are those microscopic forms which have only lately been discovered. The number of parasitic animals decreases rapidly as we ascend in the evolutionary scale, as might be expected. The many parasitic worms have already been referred to, as also the parasitic insects. But among the vertebrates, only one family of fishes is parasitic, these being best represented by the hagfish, or borer. This fish is to be found where the cod abounds, and it lives by penetrating into the body of the cod, and feeding upon its flesh. Nominally and technically, no parasites are to be found elsewhere in the whole great scale of vertebrates; but, psychologically and actually, we all know that the universal tendency towards parasitism is exhibited in not a few members of our own species, and that the universal penalty, which is degeneracy, is always exacted of them.

Though parasitism is so widely distributed throughout living nature, its presence does not always connote the existence of disease on the part of the host. On the contrary, just as we are the hosts of many microbic forms of life which do us no harm, so we find that parasitism elsewhere in most instances causes no serious injury to the host.

The way in which animals accommodate themselves to parasites

This is what we should expect to find under long-standing conditions, where evolution has reached a kind of stable state. Obviously, a parasite which exterminated the host upon which its own existence depended would itself become extinct; and that may have often happened. It is by

no means to the interest of the parasite to destroy its host, any more, indeed, than that its host shall destroy it. The best arrangement for the parasite is one of equilibrium, in which it is tolerated by the host; and that means that the host ceases to suffer, or to suffer appreciably, from the presence of the parasite.

If, now, we study the facts in some country where the conditions have long been constant, where man has neither exterminated old species nor introduced new ones, nor domesticated wild forms and introduced them to an abnormal mode of life, we find the state of balance just described. Numerous parasites will probably be found in the blood and tissues of the wild animals. These may resemble, or be even identical with, parasites which we ourselves or our domestic animals have reason to fear. But under the natural conditions they do no harm, for a state of equilibrium has been attained. Their hosts accommodate them, but thrive in spite of them. The question arises—how has this adaptation been achieved? The answer to it is very important, for it will guide us as to the prospects of any new species, such as ourselves or our horses, which propose to settle in the district.

Theories of how immunity from the parasite it harbors is reached by the host

One view is that, by a steady process of natural selection, carried on through many generations, the host has reached a state of immunity to harm from the parasite which it harbors. Susceptible individuals have been persistently exterminated; while those which happened to vary in the direction of resistance would survive, and transmit their advantage to their offspring. In course of time there would thus be evolved an immune race, but its immunity would be by no means shared by any newcomers who had not been through the same discipline. This is one interpretation, of which the chief exponent, for many years, has been Dr. Archdall Reid, himself born in and long a resident of India. But the problem is exceedingly complicated, and other interpretations are possible. Thus, the state of balance and immunity on the

part of the host may have been reached because, in the course of generations, those strains of the *parasite* which were most deadly have exterminated themselves by the destruction of their hosts, while those which were less ruthless have spared the host, and have thus survived. In other words, the evolution may have occurred in the parasitic species, and not in the host species at all.

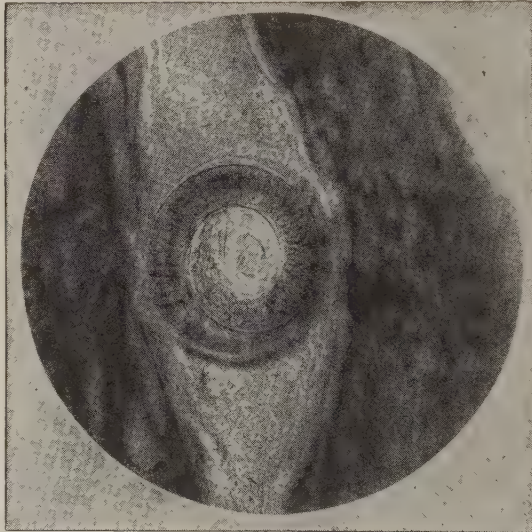
A third explanation, which may be called Lamarckian as against the former, which are Darwinian in principle, is that the individuals of the host-species have personally acquired some degree of resistance to the parasite, involving a profound and general modification of their body chemistry, and this "acquired immunity" has been transmitted to their offspring. The thoroughgoing Darwinians deny, *in toto*, the possibility of any such thing, on a variety of grounds which are quite arbitrarily laid down. It may be the true explanation, after all. In any case, the problems involved in this connection concern the future of mankind in the most intimate way.

The control of the tropics, the mastery of disease, the spread of civilization, the ultimate total numbers of the human population of the earth and the proportions thereof contributed by the various races — all these largely depend upon the problems of parasitism. Thus, to take a familiar example, we speak, or used to speak, of a certain part of Africa as the "White Man's Grave", because of the liability of white men to fall victims to malaria there. If we examine the children of the natives in such regions we find their blood swarming with malaria parasites. They do not suffer as we do. Assuming that the parasite must remain (though in

many instances the problem can be abruptly solved by the extermination of the parasite) we have to decide whether, and, if so, how, the white man can reach the immunity enjoyed by the native; and we have also to decide whether this is really an immunity worth having, or whether, in point of fact, the native race is not degenerate, the victim of racial poisoning through generations of parental malaria, as Sir Ronald Ross believes.

In cases where the parasite can be exterminated by man, a new factor in evolution, which identifies it, and destroys its breeding places, no further problem remains. But in many instances man cannot do so — at

any rate, yet; and the question arises — what is he to do? Sharp controversy will now arise between the exponents of the various interpretations which we have just looked at. The pure Darwinians, strenuously teaching what Darwin repudiated, will argue that only natural selection by the parasite will produce immunity against it. In the case of tuberculosis, for instance, which we shall shortly have to con-



A PARASITE ON MAN — *TRICHINA SPIRALIS* ENCYSTED IN MUSCULAR TISSUE

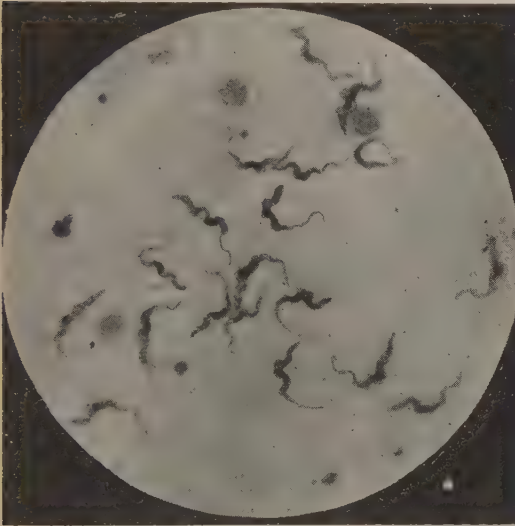
sider in detail, they say that medical science and philanthropy can only interfere with the sole means by which a race may acquire immunity to a disease — namely, by the gradual elimination of the most susceptible. They argue that in this way alone can a race be made strong; while the Lamarckians argue that in this way it will be made weak, owing to the cumulative action of the disease-poison upon successive generations. These are differences which, in fact, cannot be resolved upon paper, for it all depends upon what we begin by assuming; and they require exact observation as to what actually happens in nature itself.

But in any case it is true that the facts of parasitism play a very large part in evolution, and in the distribution of living forms. To take our own species as simply one among millions, evidently its geographical distribution has depended in the past, and depends at the present moment, upon the distribution of certain parasites. Where they abound, man is absent, or is found in only very small numbers. Mere physical conditions trouble him little. He penetrates everywhere, as all species try and tend to do, but the barriers which he cannot penetrate are those set up by parasites which would destroy him. Within those barriers there may exist certain small

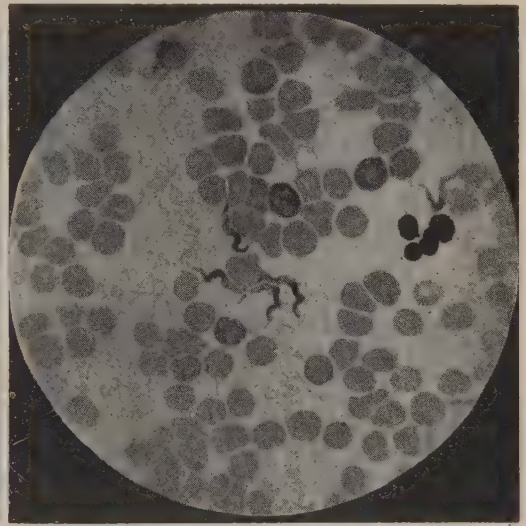
assistant, in any or all of the ways we have discussed. Or else the species simply does not occur where the parasite or the potential parasite occurs.

On the whole, then, the fact of parasitism does not connote any appreciable quantity of disease in a state of nature. The internal characteristics of species, host and parasite, and their distribution, are so evolved that, in general, disease exists to only a very small degree.

But this we begin to appreciate only when we observe the consequences of any interference with the existing adaptation. We modify our own conditions, as in the formation of great urban aggregations, and



TRYPANOSOMES TRANSMITTED TO HORSES AND CATTLE BY TSETSE FLIES



TRYPANOSOMES OF SLEEPING SICKNESS TRANSMITTED TO MAN BY A BITING FLY

numbers of men, either degenerate or else specially adapted, and resistant within limits, but a non-adapted race cannot pass them without heavy penalties. On the other hand, members of the race within the area of parasites may be removed, and then multiply amazingly, like the negroes in the United States. What is true of man is true of many other species of animals and plants. If we examine their distribution and its limits we find that they are determined by the presence, beyond those limits, of creatures which would become parasitic upon them. Under the conditions of nature, things have mostly adjusted themselves. Perhaps a species has become re-

promptly find ourselves the victims of many parasites. We penetrate to places where our race has undergone no evolution — Darwinian, Lamarckian or other — and again the result is disastrous. We take our horses with us to serve us, and find them the victims of an infection, transmitted by a blood-sucking fly, to which the native animals are practically immune. Just the same happens with many of the plants which we desire, and introduce into novel situations.

The work of the last few years, beginning with the labors of Sir Patrick Manson and Sir Ronald Ross, now a long time ago, has given us a general picture of parasitism

which may apply to many cases hitherto obscure. First demonstrated in the case of a kind of malarial infection in birds, it is now seen to be a fair statement of a practically world-wide state of things. We have seen that the animal kingdom may be subdivided into two great parts, the invertebrates and the vertebrates. These latter culminate in the mammals, and more especially in man. At the head of the invertebrates we find a vast variety of insects. The struggle for existence, and for the possession of the world, is largely seen to resolve itself into a curious contest between certain of these insects and man himself. But it would be no contest worth mentioning if the insects were merely parasitic upon the blood of man and no further complication existed. In that case the insects would be no more than inconveniences. Fleas are a nuisance, but they do not actually limit the distribution of the human species, or keep down its numbers; or, at any rate, fleas do not in this country. The loss of a little blood, to feed so small a creature, really does not matter.

The world-problem depends upon the fact that the parasitic insect is itself the prey of parasites. The insects which are not, such as fleas in this country, do not matter for evolution. They are merely a nuisance. But many insects matter immensely for the future distribution and quality of life upon our planet, not merely because they are parasitic upon man and other vertebrates, but because they are themselves the hosts of parasites which occupy a place very low down in the animal scale or sometimes in the vegetable scale, as in the case of the bacillus of plague. The insects distribute, in various ways, the parasites which invade them. In some cases, as we shall see, the insect is merely a vehicle, not essential for the maintenance of the life of the parasite. Such seems to be the rat-flea in conveying the bacillus of plague from the rat to man. But in other cases the vital relations are much more complicated, for the minute parasite requires to pass a necessary part of its life-cycle in the body of the insect, and another part in the body of the mammal that the insect bites. This parasite

thus becomes the instrument with which the insect wages against man, or animals valuable to man, the fight for the possession of the world; and upon the solution of these problems, as we shall see, depend the hygiene and the destiny of the tropics.

Thus from the biological problem of parasitism in general we pass to the special problems of the conquest of disease, in so far as that depends upon parasitism. Close acquaintance with parasitic disease has taught us that it is largely a matter of chemistry — the special chemistry of the parasite and of the host, and the relations between them. Given sufficient knowledge of chemistry and of the special biology of the parasites, problems of disease thus become soluble. In surprising but unequivocal fashion they are removed from the sphere of the doctor. He may study his patients and their symptoms with infinite assiduity, but he will never be any nearer the understanding of the causes some of the results of which are all that he can detect. His experience, his stethoscope, his skilled touch, trained eye, everything characteristically medical about him, including his knowledge of drugs and of the art of prescribing — all these are set aside. The greater part of all disease is seen to be not a medical problem at all.

Medicine, which is literally the business of healing, may be allowed to rule in the actual care of the patient, but the essential problems, the solution of which will make all medicine by so much superfluous, are not medical at all. They are biological and chemical — any number of lifetimes of clinical experience would leave us where we were in regard to them.

When we look backwards we see that our knowledge dates, on the whole, from a single man, who never held a medical degree, but was essentially and originally a chemist; but he carried his chemistry to such lengths as ere long made him the greatest doctor of all time, the father of preventive medicine. In due course this chemist, Louis Pasteur, became a master of a great province of biology; and as such he falls to be considered now, at the beginning of our study of the conquest of disease.

DISEASES OF GARDEN PLANTS

Common Maladies of the Potato, Tomato,
Bean, Beet, Lettuce, Cabbage and Onion

METHODS OF PREVENTION AND ERADICATION

PRACTICALLY every wild and cultivated plant is injured to a greater or less degree by one or more parasitic organisms. The diseases which result are, however, in some cases of so little importance that the vigor of the plant is not impaired. Cultivated crops are usually diseased to some extent, but often the resulting financial loss is insufficient to warrant the expenditure of time and money for its prevention. In other cases the same or a different disease may involve the total loss of the crop. Weather conditions play an important part in determining the seriousness of plant diseases. Rainy periods are usually followed by destructive outbreaks of certain maladies, due to the fact that the presence of abundant moisture favors the rapid development of the parasite. In one season, for this reason, a given disease may be very destructive, while in the next practically no trace of it may be found. One week a field or garden may present a healthy appearance, and the next week half the plants may be ruined. A large element of chance enters, therefore, into the raising of most plants. The wide-awake, modern grower may, however, insure himself against serious loss by using standard methods of prevention.

Few plant diseases caused by fungi or other microorganisms can be cured after the plant has actually become affected. The entrance of the parasite into the interior of the plant can, however, usually be prevented. Fungicides are used primarily to prevent injury rather than to cure that which has already taken place.

In this respect the treatment of plant diseases differs radically from that in vogue in the treatment of disease in man. In reality the fungicide serves as a protecting armor to the plant; but in most cases after the fungus has gained an entrance it is then too late and absolutely useless to apply the fungicide. In a few cases, in which the fungus is normally largely external on the host, such as the powdery mildews of roses, hops, lilacs, cherries and other plants, dusting the affected portions with sulphur will kill the organism and restore the host to health.

Not all methods of disease control have to do with the application of fungicides. Pruning out of affected parts, various types of seed treatment, soil sterilization, crop rotation, the application of various substances to the soil, drainage, the complete eradication of alternating host plants, the destruction of insects carrying the disease germs, the planting of immune or resistant varieties of host plants, and exclusion of diseased plants from a given territory by federal or state inspection or quarantine constitute some of the other remedies.

The implements for combating plant disease should be always on hand and in condition for use, and the application of a spray on short notice should be possible. No grower who hopes to obtain clean crops should trust to chance. He should have always available the means for fighting the many fungi and bacterial foes which are sure sooner or later to assail his plants. In the use of spray mixtures the owner of a small garden will find

it more advantageous to use the proprietary mixtures which are put on the market as fungicides than to attempt to mix his own materials. Large growers of any crop will, however, find it cheaper to buy the ingredients and prepare their own mixtures. Spray nozzles and other apparatus can be bought at any hardware store.

Diseases of garden crops annually exact a toll which aggregates in the country as a whole in any season an enormous total. If every gardener would combat the diseases which appear in his own small plot of ground a greatly increased production would be effected and the high cost of living would be proportionately reduced.

Some of the common diseases of the potato and their remedies

Since potatoes constitute so important a part of the diet of the American people, and because of their high price in recent years, it is especially desirable that disease in this crop be eliminated. The potato plant is subject to attack by a considerable number of parasitic organisms, and each year a new parasite seems to join the ranks or prove more destructive. The most serious disease of the potato is late blight caused by *Phytophthora infestans*. This organism and the disease which it produces have, however, been discussed at length in another chapter and need not be considered here. Another common disease of the potato is scab. This malady may be recognized from the typical disfiguration of the tuber, which shows slightly raised, irregular, corky scab spots on the skin. The lesions caused by this disease are wholly superficial. The inner lying tissue of the tuber is not penetrated, and the appearance and vigor of the plant above ground are not affected. The tubers are merely rendered unsightly and the price which they will command on the market is substantially reduced. For the elimination of this disease several measures looking forward toward prevention must be carried out. Tubers apparently undiseased should be selected for seed. They should then be soaked before cutting for two hours in a formalin solution made by di-

luting one pint of formalin in thirty gallons of water. Only clean soil should be used; soil which has previously been planted with potatoes should be avoided. The application of lime or wood ashes to the land is very undesirable. Since an alkaline soil is favorable to the parasite "souring" by green manuring or plowing under of a green crop such as clover is recommended. When very large lots of potatoes are to be planted soaking the tubers in formalin involves such an enormous amount of labor and so many receptacles that the method meets with disfavor among growers. In the search for a more satisfactory method of seed treatment gaseous disinfection suggested itself, and experiments were carried on with several gases, among them the fumes of sulphur. Formaldehyde gas obtained by the evaporation of formalin has, however, proved the most effective. This method may be briefly outlined as follows.

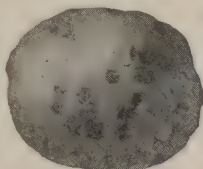
Simple directions for making an effective disinfecting chamber

It is first necessary to have a perfectly air-tight disinfecting chamber. For this purpose a room in a barn may be partitioned off, and the floor, side walls and ceiling covered with an air-tight coating of builders' paper. Slatwork crates having a capacity of about two barrels are recommended for holding the tubers while they are being treated. These should not be over nine inches deep. The crates may be arranged in vertical tiers in a framework made by erecting 2×4 scantlings as uprights and nailing upon these 2×2 cross pieces for supporting the crates one above the other. They should be arranged in such a way that the crates may be pulled out as the drawers from a cabinet. There should be abundant space at the back and sides, and between the bottom of one crate and the top of the next crate beneath to allow for free circulation of the gas on all sides. In the center of the room there should be an open space, preferably a wide aisle, to facilitate the filling and removal of crates and to leave room for the generation of the gas.

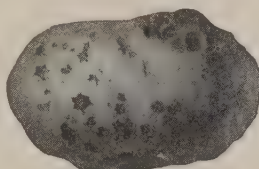
For a generator a small galvanized iron wash-tub about 15 inches in diameter may be used. On account of the heat evolved in the generation of the gas an earthenware receptacle is unsatisfactory, and a shallow vessel is to be avoided since there is considerable danger of the contents boiling over on to the floor. The generator should be placed in the center of the room on the floor or elevated somewhat on a box or stool. When ready to generate the gas a quantity of crystals of potassium permanganate should be sprinkled evenly over the bottom of the tub. Then the formalin should be poured over these, and the tub given a rapid tilt to insure wetting all the crystals. The operator should then retire quickly from the room, closing the door tightly from without. Forevery 1000 cubic feet of space in the room 23 ounces of potassium permanganate and 3 pints of formalin should be used. The room should remain closed for 48 hours and since the gas has a very corrosive effect on the mucous membrane of the nose and throat the operator should avoid breathing it. After the room is opened, considerable time should be allowed for the escape of the gas before an attempt is made to enter. When first mixed the potassium permanganate and formalin show little change, but soon a violent foaming and boiling is set up and the formaldehyde gas is liberated. The materials employed in this process are not expensive, and the gas necessary for 1000 cubic feet of space may be generated for about three dollars. The expenditure of many times this much money would be a good investment, considering the amount of the losses which a grower suffers from this disease.

Several other diseases of the potato cause excrescences over the surface of the tuber. Two of these, the powdery scab and black wart, are more serious than common scab since the tuber suffers more pronounced malformation. Neither of these diseases is as yet common in this country, and the federal quarantine board is using every effort to prevent their spread throughout the potato-growing sections. If they become widespread they will be exceedingly destructive. The powdery scab is caused by a slime mold, *Spongospora Solani*, while the black wart is due to a fungus, *Chrysophlyctis endobiotica*. No very effective methods of control can be recommended for either.

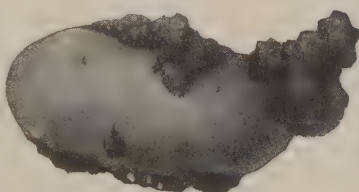
A serious disease of the foliage of the potato is "early blight" caused by *Alternaria Solani*. This is a typical leaf blight and may be easily distinguished from the late blight previously described and from other pathological conditions of the leaf by definite characteristics of the lesions produced. The spots are



Common "scab" of potato disfigures the surface but does not affect the inner tissues of the tuber.



"Powdery scab" of potato. The dark pustules contain the spore powder of the slime mold, *Spongospora Solani*.



The dread "black wart" disease of the potato which has spread rapidly through Europe.



A rot of the potato caused by "late blight"

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COMMON DISEASES OF THE POTATO

oval, and distinctly marked with concentric lines like a target. They are scattered irregularly over the leaf but in severe infections may be confluent. The disease results in the early death of the leaves, and the vines dry up prematurely, resulting in the production of small tubers, and not infrequently in the loss of 50 per cent of the crop. Spraying of the plants with Bordeaux mixture will also control this disease. Early blight also appears on the tomato, jimson weed and other closely related host plants.

The tomato is not subject to attack by so many serious diseases as is the potato. In the United States it is, however, affected by two maladies worthy of note.

These are "blossom end rot" and "leaf spot". The former makes its appearance in the development of a spot at the blossom end of the fruit. This spot is accompanied by a characteristic dry rot and the lesion turns black. Unlike most plant diseases this one is not due to a parasitic organism. It is physiological in nature and induced by a too sudden checking of the water supply, or by too frequent watering. Another name applied to the disease is "oedema". It can be avoided by the use of proper methods of cultivation, which will insure for the plant a uniform supply of water through-

be controlled only with great difficulty since the fungus passes the winter in the old dead leaves which fall to the ground. When setting out plants it is desirable to pinch off all the lower leaves that might touch the ground, and also all those which bear spots of any kind. These should of course be removed and burned. If the plants are sprayed very thoroughly on the under side of the leaves every week or ten days with Bordeaux mixture of the 5-5-50 formula the disease can be greatly reduced.

Three serious and widespread diseases of the common garden bean cause great loss to the growers of this plant every year. Of the three, anthracnose is certainly the most destructive. Some growers speak of this disease as "rust". It is not, however, a true rust, since the fungus concerned, *Colletotrichum Lindemuthianum*, is a member of a widely separated group. The disease may be recognized by the presence on the pods of unsightly depressed spots. These appear at first as small brownish or purplish areas of discoloration. Later, with the increase in size of the spot, the center becomes depressed and masses of pink spores are developed at its center. The fungus also attacks the stems, leaves and cotyledons but it is most conspicuous on the pods. The disease is carried over the winter in affected seed. Only clean seed obtained by selecting clean pods should be used for planting. The sorting of seed fails to control the disease because the fungus may be present in seed which to the eye appear clean. A pod which looks clean, however, never contains diseased seed. Seed treatment, moreover, is ineffective. Careful spraying of the plants with Bordeaux mixture, 5-5-50, will reduce the amount of the disease. Three applications of the spray should be made during the growing season, the first when the plants break through the ground, the second when the first pair of leaves are fully expanded and the third when the pods begin to form. A hand sprayer should be used and the plants thoroughly covered.



LEAF SPOT OF TOMATOES

1, leaf attacked by fungus; 2 and 3, magnified portions of diseased leaf; 4, section through leaf showing fruiting conceptacle magnified; 5, spores of the fungus, highly magnified

out the season. Other similar physiological diseases are "stippen" of apples and oedema of cabbage and certain other plants.

Leaf spot of tomato is a destructive foliage disease, due to a fungus, *Septoria Lycopersici*. Numerous definite, small, angular spots with pale centers and colored borders appear on the leaves. Petioles and twigs may in severe cases be also affected. The leaves curl up, die and fall off. The disease may be recognized by the fact that it makes its appearance first on the lower leaves and works upward toward the top of the plant, killing the leaves in turn as it advances. It can

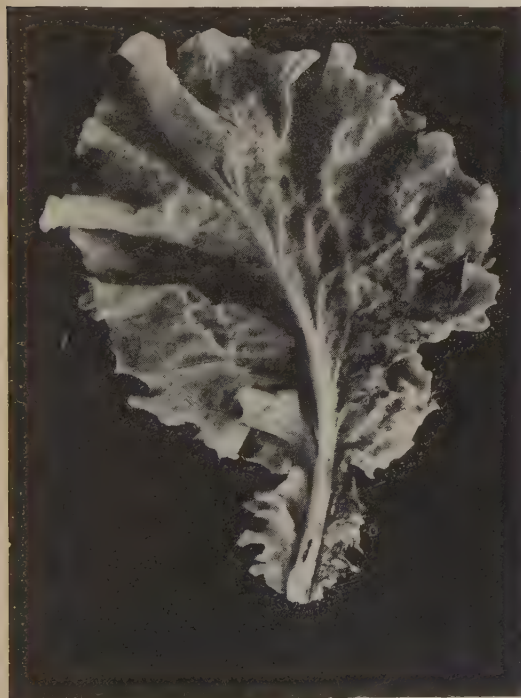
COMMON DISEASES OF GARDEN PLANTS



Raspberry canes, showing large excrescences caused by the "crown gall" organism, *Bacterium tumefaciens*.



"Anthracnose" of beans. Pods showing prominent lesions due to the presence of the anthracnose fungus, *Colletotrichum Lindermuthianum*.



A lettuce leaf showing prominent disease spots caused by *Marssonina Panattoniana*.



"Club root" of cabbage. A young plant with the roots diseased and hypertrophied due to the attack of *Plasmodiophora Brassicae*, a slime mold.

Bean blight is in some localities more destructive than anthracnose. It is of bacterial origin, the causal organism being *Bacterium Phaseoli*. This disease also is extremely difficult to control. The organism probably hibernates in the seed. The planting of clean seed from clean pods, and the application of the three sprays of Bordeaux mixture as for anthracnose will reduce the grower's losses, but no wholly satisfactory control measures have been evolved. With favorable weather conditions the disease is very destructive. It affects chiefly the leaves, causing large dead brown areas.



LEAF DISEASES OF CELERY

1, celery leaf spot; 2, and 3, perithecium and spores, highly magnified; 4, septoria on celery-leaf; 5, section of perithecium of septoria embedded in a leaf; 6, spores of septoria, highly magnified.

The pods, however, frequently show spots not unlike those caused by anthracnose.

Another serious disease of the bean is caused by a soil fungus of the genus *Rhizoctonia*. This organism attacks the plant in the soil and causes a rot of the stem just at the surface of the ground. Depressed shriveled areas of a reddish brown color are formed. If the plant is very young when attacked, damping off may result, and at any age the weakening of the stem makes more likely the breaking over of the plant. In the roots an extensive dry rot may develop and the small lateral roots be destroyed.

Other plants attacked by *Rhizoctonia* are sugar beet, carrot, cabbage, cauliflower, cotton, lettuce, potato, radish, sweet potato, pumpkin, water-melon and pea.

The common garden beet and the sugar beet are affected by several diseases. Of these the leaf spot caused by the fungus *Cercospora Beticola* is the most widely distributed and the most destructive. The leaf spots are at first small brown points with reddish purple borders. Later when they reach a diameter of 4 mm. or more the center becomes almost white. On these spots long filamentous, many-celled spores are formed. These are blown to other plants, or, falling to the ground, are able to retain their power of germination for months. The diseased plant presents a characteristic appearance in the field, the crown of the plant being considerably more elongated in a vertical direction than is normal. The leaves blacken and dry up gradually from tip to base and as they become dry they stand more nearly erect. Spraying with Bordeaux mixture will control the disease and since the spores hibernate on the ground early spraying is essential.

Lettuce is attacked by damping off fungi such as *Rhizoctonia* and *Pythium Debaryanum*; and is also affected with several more specialized diseases of which "downy mildew of lettuce" and "lettuce drop" are the best known. The downy mildew of this host is caused by *Bremia Lactuæ*. This disease is not infrequent when lettuce is grown in greenhouses, and it may occur in the fields in cool weather, particularly in the autumn. The frost-like growth of conidiophores appears first on the under side of the leaf. The affected areas then turn to a paler color, and the leaf soon wilts. The disease may be easily controlled in the greenhouse by supplying the plants with a large amount of light and ventilation. A more serious disease of lettuce is "drop" caused by *Sclerotinia Libertiana*. The same fungus causes a similar disease in other greenhouse and garden crops, including cucumbers, rape, tobacco and many forced vegetables and bulbous plants. On lettuce the disease first

makes its appearance in the production of water-soaked areas on the stem and basal portions of the leaves. There may be also some slight production of mycelial threads of the fungus over the surface of the leaf, and on these minute black more or less globose bodies which are called sclerotia. The disease spreads rapidly, and ultimately the entire plant collapses and seems to melt into a shapeless mass of decaying leaves. This fungus is widespread and is one of the most serious greenhouse pests. The disease may be controlled by steam sterilization of the soil to a depth of two inches or more. While the plants are growing the surface soil should be kept loose and dry. Another serious disease of lettuce in certain sections is a leaf spot caused by *Marssonina Panattoniana*.

Where onions are grown in any quantity this crop is frequently seriously diseased. Two diseases, "mildew" and "smut", occasion the greatest loss. The mildew caused by *Peronospora Schleideniana*, is also known to growers in various sections of the country as "blight" or "mold". There have been several serious outbreaks of the disease in America. The fungus is a close relative of the organisms causing "late blight of potatoes" and "mildew of lettuce". On the onion the disease appears in June or July and the grower will notice on the leaves while they are still covered by dew a peculiar downy appearance of a violet hue. This is caused by the layer of conidiophores of the fungus. The diseased plants wilt down rapidly and do not recover. A field of onions in which this disease has run its course looks as if it had been sprayed with boiling water. The young plants appear to be somewhat less susceptible than the old. If the crop is sprayed frequently with Bordeaux mixture after June 15, when the disease is beginning to appear, it can be controlled. Crop rotation is also advised. Old onion tops, in which the oöspores of the fungus hibernate, should be destroyed.

Onion "smut" has long been known as a serious disease of this host. Seedlings are attacked soon after the first leaf is formed, and dark spots soon appear on all the leaves. These spots become

longitudinal rifts filled with black powder. Similar rifts appear on the bulbs. The powder is made up of a large number of spores in little aggregations called "spore balls". The fungus is closely related to the cereal smut fungi, and the black spore powder in the two cases is much the same in appearance. In the control of this disease seed treatment is useless, since the fungus lives in the soil. Onions should be set out in clean soil. Crop rotation



1, EUROPEAN, AND 2 AND 3, AMERICAN GOOSEBERRY MILDEW

should in so far as possible be constantly practised. In planting the seed a mixture of 100 pounds of sulphur and 50 pounds of air-slaked lime to the acre should be drilled into the rows. This will greatly reduce the disease.

Strawberries, raspberries, currants, gooseberries and others of the so-called small fruits are also frequently attacked by fungi. Every garden crop in fact has its diseases, and it has been possible in this limited space to describe only a few typical maladies on the more important.

THE BUSY CARPENTERS OF THE FOREST



FLICKER FLYING TO ITS NEST

REDHEADED WOODPECKER FLYING TO NEST

FLICKER NEAR ITS NEST

DOWNY WOODPECKER WITH FOOD FOR ITS YOUNG

YELLOW-BELLIED SAPSUCKER HARD AT WORK

The illustrations in this chapter except those on pages 3351 and 3353 are from photographs by A. A. Allen.

OUR COMMON BIRDS V

Woodpeckers, Hummingbirds, Swifts,
Whip-poor-wills and the Nighthawks

THE BUSY CARPENTERS AND WEIRD NIGHTHAWKS

FEW birds are more easily recognized by the amateur ornithologist than are the woodpeckers. In spite of the fact that they constitute a large family (*Picidae*) of over three hundred seventy-five species and are found over the entire world, except in Madagascar and the region of Australia, they are remarkably uniform in their habits and in their modifications. Indeed, some of the distinct and even strikingly marked species, like our downy and hairy woodpeckers, resemble each other almost feather for feather. Twenty-four of the nearly two hundred species of woodpeckers occurring in the New World are found in North America.

The typical woodpeckers have large heads with stout chisel-like bills which end in a narrow edge rather than a point, and are thus well suited for chipping wood. Their tongues are very long, capable of being protruded a couple of inches beyond the tip of the bill, and have recurved barbs at the tip. This combination of bill and tongue makes a perfect tool for drilling into the chambers of wood-boring larvæ and spearing the concealed grub. For this reason woodpeckers are considered one of the most valuable groups of birds.

The tail feathers of the woodpeckers are very stiff and pointed and serve as props to support the weight of the birds as they climb the trunks of trees in their characteristic manner. The tiny woodpeckers of South America and Africa, called "piculets", and the four species of wrynecks of the Old World, however, have soft tails without spinous shaft tips.

The feet of woodpeckers, likewise, are adapted to this climbing habit and differ from those of all the birds that we have thus far considered except the cuckoos in having two toes directed forward and two backward. Thus they serve as pincers for better grasping the bark. In a few species, the three-toed woodpeckers of northern North America, one hind toe has been lost.

Because of all these modifications, the woodpeckers are separated from the order *Passeres*, or "perching birds," and are put in an order by themselves, the *Pici*.

In color, the woodpeckers vary from the common black and white varieties, through various shades of brown and green, to those that are brilliant scarlet and yellow. In fact, patches of scarlet are found on the heads of the males of most species, even the most dully colored.

They are usually solitary birds and even the family parties disperse soon after the young are able to care for themselves. Our northern species, however, sometimes gather in scattered groups during the winter, often accompanying the flocks of chickadees and nuthatches, and regularly come to feeding stations maintained for them. In fact, they become so fond of suet that they continue to visit pieces hung in the trees all through the summer months, even when they drip in the sun and become rancid. They even feed their young with some suet and bring them to it when they are able to fly.

In nesting habits, also, woodpeckers are remarkably uniform, for they all drill holes in dead or soft-wooded trees and lay their eggs on the chips at the bottom of the cavity.

The size of the hole varies from about one and a quarter inches in diameter with the downy to two and a half inches with the flicker, and is correspondingly larger with the pileated and ivory-billed species. The hole is directed toward the center of the tree but a short distance and then drops downward for from six to eight inches to two feet and is usually enlarged toward the bottom for the convenience of the incubating bird. Usually both birds assist in drilling the hole and often carry the chips to some distance from the tree in order not to attract attention to it. The eggs are always glossy white and unspotted, but the number varies with the different species from four to twelve. There is one celebrated case of a flicker which continued to lay as often as the eggs were removed, until it had laid seventy-one eggs in seventy-three days.

Most woodpeckers excavate new nesting cavities each year, but some return to the same hole year after year, particularly the flickers and red-headed woodpeckers. Some make roosting holes for the winter or for the male bird while the female is incubating. In Europe several species of woodpeckers have come to use artificial nesting boxes put up for them, but in this country the flicker is, as yet, the only one that does so regularly. Other species will undoubtedly learn to do so as time goes on and as available dead trees become scarcer and nesting boxes more plentiful.

To be acceptable to a flicker, a nesting box should be from six to eight inches square inside, and from eighteen inches to two feet deep. The hole should measure two and a half to three inches in diameter and should be on one side, a couple of inches from the top. The inside of the box should be rough. The best place for the box is fifteen feet or more from the ground on the straight bole of a tree free from branches, on a dead tree, or on the top of a tree that has been cut off. Inasmuch as woodpeckers build no nests at the bottom of their holes, but merely lay their eggs on the chips at the bottom, it is necessary to put about two inches of sawdust or ground cork in the bottom of the box to keep the eggs from rolling around.

Woodpeckers have no true song and their call notes are inclined to be harsh and unmusical. In place of a song, the males, and possibly the females at times, have a loud rolling tattoo which they make by hammering with the bill upon a dead limb, a loose piece of bark, a drain pipe, tin roof or other resonant surface.

The most striking member of the woodpecker family in North America is the red-headed species, found from Ontario to the Gulf and from Colorado to the Atlantic, although for some reason it is rather rare in some localities, particularly in New England. Males and females are alike with the entire head red, the back and most of the wings blue-black, and the secondaries of the wings, the lower back and underparts pure white, giving them a most conspicuous appearance, especially in flight. The males of many species of woodpeckers have more or less red on the head, but no other has the entire head red.

Redheads are versatile birds in their feeding habits, and though they drill for their food less than the downy and hairy species, they often fly out after passing insects like the flycatchers, or get down on the ground in search of ants and worms like the thrushes. Occasionally individuals arouse the enmity of the whole bird and human world by eating the eggs or young of smaller birds. In the fall of the year their presence in a locality is largely dependent upon the supply of beechnuts, chestnuts or acorns, and at these times great disputes often occur between the redheads and the blue jays for the possession of certain nut trees and for a time such trees present a riot of color. Like the nuthatches, redheads often store nuts for winter use in the crevices of the bark or in fence posts. If the nut crop is good redheads are likely to pass the winter as far north as northern New York or Ontario, but otherwise they retire south of Maryland.

More abundant in most places than the redhead is the flicker, the only brown woodpecker in the United States. The flicker is known by various local names: high-hole or high-holder, clape, wickup, wake-robin, golden-winged woodpecker and over one hundred others. The flicker is about

the size of the redhead, somewhat larger than a robin, brown above barred with black, light brown below spotted with black, and grayer on the head. Its most characteristic marks are a red crescent on the back of the head, a black crescent on the breast, a white patch on the rump and golden yellow lining to the wings and tail. The western flicker has this lining of the wings and tail red instead of yellow.

The flicker is a rather aberrant member of the family and now seldom drills for boring larvæ. Its favorite food is ants, which it secures by drilling into their nests upon the ground. Thus it is frequently seen hopping about lawns with the robins. Its bill is slightly curved and less chisel-like than most woodpeckers', and its tongue, instead of being barbed, has a sticky secretion poured upon it from the modified salivary glands which entangles the ants.

The downy and hairy woodpeckers are found throughout North America east of the Rockies, and are perhaps the best known of all the woodpeckers. The northern and southern birds have been separated into distinct races because of slight differences in size, but, to all appearances, the birds are the same. The two species are almost exactly alike, except for size, the hairy woodpecker being about the size of a robin (9.4 inches in length), and the downy somewhat larger than a sparrow (6.8 inches). Both birds are striped black and white above, and pure white below, about the only difference being that the outer tail feathers of the hairy are pure white, while in the downy they are barred with black. The males of each species have a crescent of bright scarlet on the back of the head, that of the hairy being divided through the middle by black. Both species are permanent residents where found, and often nest in the vicinity of the place where they are fed in winter.

Another familiar species of the Southern States, ranging as far north as southern New York, is the red-bellied woodpecker. It is a noisy bird about the size of the hairy, but with the whole top of the head red and with the back barred rather than striped. The red of the belly is quite inconspicuous. Like other woodpeckers, it is fond of suet.

The largest of all the woodpeckers is the ivory-billed species, a bird about the size of a crow, and fully as black, with a scarlet crest, a white stripe on each side of the neck, and large white patches in the wings. It was formerly not an uncommon bird in the larger forests of the South Atlantic and Gulf States but now is confined to the largest and most remote cypress swamps of the lower Mississippi Valley and Gulf States, where it is on the verge of extinction. It is a wild, shy bird, and cannot withstand the encroachments of civilization and the lumber mill.



"NEST" AND EGGS OF DOWNY WOODPECKER

Nearly as large and much more widespread, though confined to the forests, is the pileated woodpecker. It is similar in color to the ivory-billed, but has somewhat lighter underparts and does not have the white in the wings so conspicuous, or the ivory-white bill. The northern and southern forms of this bird range from Quebec to the Gulf, but it is nowhere a common bird. In the cypress swamps of Georgia and Florida, however, it occurs in numbers.

The red cockaded woodpecker is one of the less well-known woodpeckers of the South, found in the pine forests. It is similar to a hairy woodpecker in general appearance,

but has the back barred with black and white and has black streaks on its sides.

The three-toed woodpeckers, of which there are two species inhabiting the boreal regions and coming southward in winter to northern United States, are also about the size of the hairy, but have an orange-yellow patch on top of the head.

In the West are found the California woodpecker, which has the habit of storing acorns in holes which it drills in the bark of trees; the gila and golden-fronted woodpeckers, which resemble the red-bellied species; the Lewis woodpecker, the greenest of North American species; the red-naped, red-breasted and Williamson sapsuckers, which are similar in habits to the eastern yellow-bellied sapsucker.

The sapsuckers get the name from their habit of drilling rows of small round holes in the bark of many species of trees and drinking the sap which collects. One bird usually taps several different trees and each one in several places, and then makes the rounds as often as the sap collects. It is interesting to note that the barbs on the tongue, so characteristic of the woodpeckers, have been modified into a fringe or brush for collecting the sap. Sapsuckers eat likewise such insects as are attracted by the sap and, like the red-headed woodpeckers, are quite expert at catching insects on the wing. In addition they eat some of the soft inner bark exposed when the holes are being drilled, and, in soft-wooded trees, like the poplar, where the sap does not flow freely, and the cambium is almost gelatinous, they sometimes peck off fairly large areas. Ordinarily their rows of holes do not overlap and little or no damage is done to the tree, but sometimes, when the birds are very numerous, and for some reason persist in attacking a particular ornamental evergreen or mountain ash, they ruin its appearance, seriously weaken it or even kill it. The holes drilled by the sapsucker often stain the underlying timber, causing what are known as "bird pecks", and are said by lumber dealers to cause a devaluation to timber of the United States of nearly a million dollars annually.

At times sapsuckers behave in an erratic and foolish manner, zigzagging through the

trees with no apparent reason, flying into windows or walls on the sides of houses, even becoming so stupid as to allow themselves to be picked from the trees, or alighting on one's person and climbing up his leg as though it were the limb of a tree. It has been suggested that the sap ferments in the sun and that the sapsuckers become intoxicated, but this theory has by no means been proved.

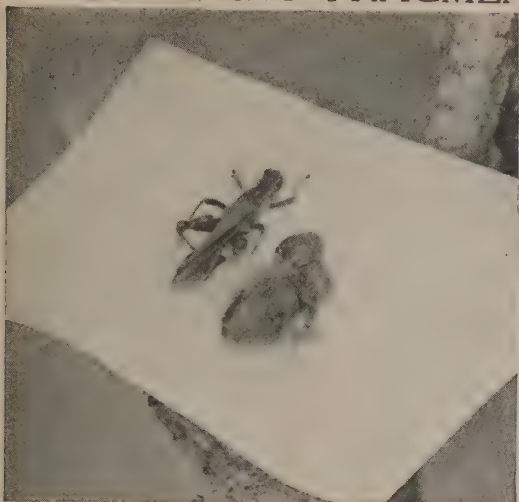
The common sapsucker of the East is the yellow-bellied species. It is about the size of a hairy woodpecker with the same general appearance, but has the throat and the whole top of the head red. It has also a conspicuous white stripe on each wing, a black crescent on the breast, and slightly yellowish underparts which are somewhat streaked. The female has a white throat and immature birds have the top of the head black.

The hummingbirds

The smallest bird in the world is the "fairy hummingbird" found in Cuba. It measures two and a quarter inches from the tip of its bill to the tip of its tail and weighs but a fraction of an ounce. All hummingbirds, however, are not so small. Indeed, the giant hummingbird, inhabiting the higher peaks of the Andes, is over eight inches long and resembles a swallow. The majority of the five hundred and eighty species and sub-species, however, are tiny birds under four inches in length.

In addition to their small size, hummingbirds are noted for the brilliancy of their colors. "Glittering fragments of the rainbow," Audubon called them, and, indeed, each hue of the rainbow, from the most delicate blues and greens to the most vivid reds and purples, can be found on some species. Sometimes the extremes of color, in wonderful combination, are found on the back or breast of a single bird. The colors are not real pigment, however, but are caused by the refraction of light due to the structure of the feather, and appear brilliant only by reflected light. Thus even the most brilliant members of the family appear somber in many lights, and as they flit from flower to flower, they alternately flash and fade in ever changing beauty.

GLITTERING FRAGMENTS OF THE RAINBOW



DAY OLD HUMMINGBIRD COMPARED WITH GRASS-
HOPPER



HUMMINGBIRD FEEDING AT TRUMPET VINE OR
CREEPER



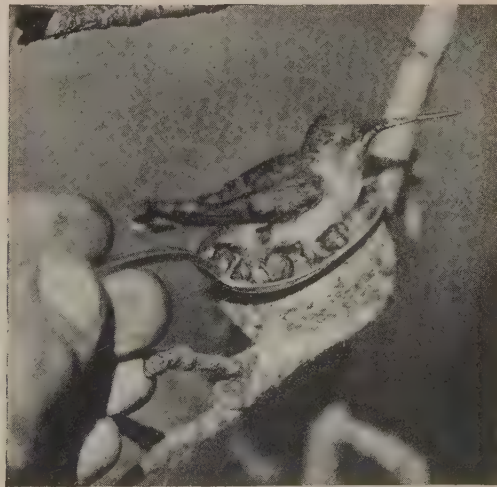
FEMALE RUBY-THROATED HUMMINGBIRD TURNING
ITS EGGS



FEMALE FEEDING ITS YOUNG BY REGURGITATION



YOUNG RUBY-THROATED HUMMINGBIRD PERCHED
ON A BLADE OF TIMOTHY



A HEAPING TEASPOONFUL — ADULT RUBY-THROATED
HUMMINGBIRD AND NEST

Many species are curiously ornamented with elongate tufts of feathers about the head or breast. Other species have greatly elongate tail feathers four or five times the length of the bird, and these are sometimes enlarged at the end, or racquet shape. Still others have dainty little pantalets of fluffy white feathers about the legs.

In spite of their great variety and the abundance and the wide range of some species, hummingbirds are found only in the New World. They undoubtedly originated in the Andes of Colombia or Ecuador where the majority of species are still found, but some have spread as far as Patagonia and others as far as Alaska. They have never reached either Europe or Asia, however, and numerous attempts to introduce them have failed. The majority of species are quite local in their range, some being restricted even to a single mountain top or to a single valley. Again, although they are found all over North and South America, they are very poorly represented in some regions. Thus, while eighteen species have been found in the United States, only one species, the ruby-throated hummingbird, occurs east of the Mississippi. Some species live in the dark humid forest, others in the arid deserts, but the great majority spend their lives in the sunlit tree-tops or about clearings in the forest wherever there are flowers.

It is from the nectar of the flowers and the tiny insects lurking in the corollas that most species derive their sustenance. A few pick insects from beneath the leaves and a few others dart out after passing insects as do the flycatchers, but these are the exception. Indeed, so dependent are they upon the flowers that the bills of many species have become adapted to particular flowers. In all species the bill is probe-like and the tongue tubular for sucking the nectar, but in certain ones the bill has become very much decurved, even sickle-shaped, and in others even upcurved to help them in getting nectar from flowers having pouch-like or lip-like corollas. One species has a bill nearly five inches long and another a bill that measures scarcely a quarter of an inch. Curiously enough the two species feed at the same long tubular flowers, the

one taking the nectar in the legitimate way, the other evading nature's provision for the cross-fertilization of the flowers by drilling a hole through the base of the flower into the nectary. Indeed, it is upon the hummingbirds that many of these flowers depend for cross-fertilization, the head or the bill of the bird carrying pollen from one flower to the next.

Even as wonderful as their tiny size, their brilliant colors, or their curious modifications, are the nesting habits of the hummingbirds. The nests are skilfully constructed of plant down or wool which is gathered from ferns or catkins, fastened together and to the branch by spider webs. The outside of the nest is ornamented usually with lichen or bits of moss so that it simulates a knot or resembles the branch upon which it is placed. Usually the nest is saddled upon a branch, but with some species it is regularly fastened to the underside of the large leaf of a palm tree fern or even to a projecting cliff or an overhanging rock. Invariably but two eggs are laid and these are always pure white without spots. They are about the size of beans, sometimes smaller, and always more slender.

The voice of the hummingbirds are seldom heard and it is the buzzing of their tiny wings that gives them the name. During the courting season, however, most species give vent to their feelings with excited chipperings as they swing, with flashing wings, back and forth past the female. A few species have songs of surprising volume and melody which they sing, as do other birds, from an exposed perch on the top of a bush or tree.

By far the best-known species is the ruby-throated hummingbird, found in summer throughout eastern United States and Canada as far west as Texas. The male bird is bright emerald-green above and grayish below with a patch of brilliant ruby-red feathers on the throat that are lacking in the female. Unless the light strikes the feathers at just the right angle, both the red and the green appear dark so that when the little bird is at rest, it is usually passed unnoticed. Indeed, one is led to believe that they spend their entire lives on the wing because they are so seldom seen when resting.

Rubythroats appear from the south, where they have been wintering from southern Florida to Panama, about the first of May when the leaves are just beginning to unroll and the first blossoms of the cherry and the flowering quince are beginning to open. From that time to the middle or the last week of May, the flowering trees sometimes buzz with their wings, for although they are not at all gregarious, a tree like a horse-chestnut at the height of its flowering season may attract them in great numbers.

About the last of May, nesting begins and the dainty little cottony structure is saddled on the branch of an apple or other tree from fifteen to twenty-five feet from the ground. The outside is covered with lichens which makes it very difficult to discover. Indeed, were it not for the alarm of the mother bird and the intrepid way in which she darts at one's head when in the vicinity of the nest, it would seldom be discovered. No bird or animal is allowed to approach within a certain radius of the nest without being attacked. Be it one of its own kind or one of the largest hawks, it is attacked with the same courage.

The male is at first quite attentive, but after the eggs are laid he disappears and never assists in the incubation or care of the young. Instead he selects some favored locality where there are flowers and when not making the rounds, sits quietly on a dead branch or telegraph wire preening his feathers. The eggs hatch after two weeks of care and the young remain in the nest for about three, at the end of which they buzz from the nest, nearly as strong as the old birds. When first hatched, they are blind and naked and their bills are very short. It is at this stage that one can more easily recognize their relationship to the swifts, which are so different in adult life.

Of the seventeen other species of hummingbirds that reach the United States, only seven advance beyond the states bordering Mexico. The best known of these is the rufous hummingbird, found in summer from California to Alaska, especially in the mountains. It is reddish brown in color, the male with a fiery red throat patch that shows orange and yellowish green in

some lights. It is particularly fond of red flowers and if a person wears bright colors in the field, they often flash up to examine them.

The Swifts

Watching the chimney swifts as they dart back and forth over the housetops or circle in dark clouds before descending some disused chimney, one never suspects their relationship to the hummingbirds. Even close inspection fails to reveal much similarity except in the shape of the long narrow wings and the tiny feet. Nevertheless the kinship exists and much of their internal structure is very similar. As already intimated, if one examines the newly hatched hummingbirds with their tiny bills and large mouths or if one sees the large dull-colored giant hummer of the Andes, the relationship is better understood.

There are nearly one hundred species of swifts (family *Micropodidae*) of which about a third are found in the New World. Of these but four occur in the United States and Canada and only one, the chimney swift, is ever found east of the Rocky Mountains. This bird is commonly called the "chimney swallow", and indeed it resembles a swallow much more than it does a hummingbird, although there is no real relationship between the two, the swallows being but modified passerine or perching birds while the swifts and the hummingbirds form a very different order.

With few exceptions, swifts are sooty black birds, sometimes with white on the rump or under parts but often with no marks whatever. The chimney swift, for example, is entirely sooty and but little lighter below than above. The East Indian tree swifts are exceptions, in which the plumage has a metallic gloss and the feathers are quite silky, ordinary swifts having rather short harsh plumage.

The most interesting thing about the swifts is their method of nesting. The nests are built of sticks, straws, feathers or other material in the form of a shallow saucer, the materials being cemented together and to the wall of the cave, hollow tree or chimney by means of the birds' saliva, which is specialized into a peculiar glue.

In one group of swifts inhabiting the islands off the east coast of Asia, the nests are made entirely of this saliva. It is from these nests that the famous "birds'-nest soup" is made, and the birds themselves are called the "es-culent swifts". They nest in large colonies in caves and the gathering of the nests is an organized industry. The nests weigh about half an ounce and bring as high as seven dollars a pound. The nests have been gathered from some caves certainly for over two hundred years, yet there seems to be no diminution in the number of the birds.

The nest of the chimney swift is built of short twigs which the birds break from the tops of dead trees either with their bills or

They never perch or descend to the ground as do other birds.

Chimney swifts return from the South about the middle of April, but where they have spent the winter is still a mystery, for the chimney swift is the one bird in eastern North America whose winter quarters have not yet been discovered. It is known that they go as far as Vera Cruz and it is probable that they winter somewhere in Central America or northern South America, but it is impossible to distinguish them from the native swifts as they soar high overhead and as yet none have been collected. They are common in all parts of the Eastern States until late September or October when they



A YOUNG CHIMNEY SWIFT IN ITS
"COAT OF MAIL"



A CHIMNEY SWIFT NEAR ITS LITTLE SAUCER OF A NEST OF
TWIGS STUCK, AS WITH GLUE, IN A SILO

feet as they swoop past without stopping. An area in the chimney or silo, as shown in the illustration, is first coated with the viscid saliva so that sticks will adhere to it. Others are then added and coated with the peculiar glue until a little saucer is constructed strong enough to support the weight of the bird, or even both birds, for they sometimes sit on the nest side by side. The nest is so small, however, that the young outgrow it long before they can fly and they have to climb out and cling to the wall as do the old birds, propping themselves up with their tails. The tail feathers are stiff and tipped with spines, somewhat similar to the woodpeckers except that there are no barbs at the tip and merely the shafts protrude.

suddenly disappear. Just before this time and when they first appear in the spring, they sometimes occur in flocks of thousands and at dusk are seen circling about some tall chimney before settling to roost. For a time as they pitch headlong into the chimney and again as they rise in the morning, so numerous are they that for several minutes they look like smoke rising. At other times of the year they scatter, and it is doubtful if more than one pair ever nest in a single chimney although pairs from adjacent chimneys often fly in company and, from the fact that they are often seen in trios, it has been suggested that they are polygamous. There is yet, however, nothing further to support this belief. At times

they sail with the wings held high over the back, but more often they fly with apparent alternate strokes of the wings and gain such momentum that few if any birds fly faster. Thus they circle through the hordes of midges and mosquitoes, probably with their mouths open, for they never seem to pursue any particular insect as do the swallows.

The three swifts found from the Rocky Mountains to the Pacific are the black swift, Vaux swift and the white-throated swift, the latter being considerably larger than the others and having the throat and breast white. A most interesting discovery has recently been made in connection with the black swift. It frequently remains dormant for days at a time in the crevices of the rocks when the weather is cold and wet, in a sort of hibernation. This is most unusual among birds which ordinarily require a constant supply of food to maintain life.

Nighthawks and Whip-poor-wills

To try to understand every impression that is made upon the senses is a sign of intelligence. The dog that howls at the moon because he does not understand it is more intelligent than the dog that takes the moon for granted. We human beings know that every effect should have a cause, and, having sensed the effect, are quick to search the cause. So insistent are we if we do not discover it, that we invent one to our own satisfaction. Later on when our mistake has been rectified, it may cling to the world for generations as a rumor or a superstition. A good many generations have passed since a group of night-jars were disporting themselves one evening on a European pasture and some one inquired what they were doing. It must have been a disgruntled herdsman that offered the explanation that they were sucking the milk from the goats, but since goats never give as much milk as is desired, the explanation took hold. It was too dark to see the insects that the goats were disturbing but it was light enough to see that the birds were following the goats. So, even today, the night-jars and their relatives, the nighthawks and whip-poor-wills, must retain the family appellation of "goat-suckers" and bear the ill-will of the non-observant world.

Nor is it from this superstition alone that these strange but useful birds have come into disrepute. The idea of a bird waiting until dark before it goes about its work is enough to prejudice most minds against it, and when besides this it is responsible for some of the weirdest sounds in all nature, even the most intelligent will lend a willing ear to fictions about it. When one is alone in the forest and a whip-poor-will breaks the silence with its strange liquid notes, it is easy to understand how the Indians came to believe that misfortune was imminent when its call was heard near his tepee. And when darkness has fallen on one of our

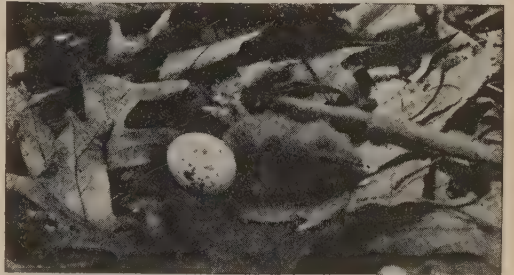
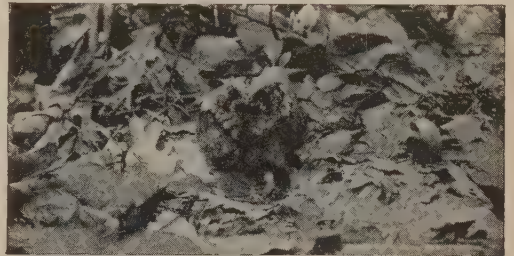


Photo by A. Dawes DuBois

THE WHIP-POOR-WILL AT HOME

The whip-poor-will builds no nest but lays its eggs on the leaves of the forest floor. The upper picture, of the bird brooding on egg and young, offers a study of protective coloration. The lower shows an egg and one of the downy young.

southwestern deserts and a chorus of poor-wills make the rocks resound, it is easy to imagine that there are evil spirits all about.

There are over one hundred species in the goatsucker family (*Caprimulgidae*), found all over the world except in arctic and antarctic regions and a few of the eastern Pacific islands. About fifty are found in the New World, the majority in the tropics, so that only six reach North America. Four of these are rather well-known birds, the nighthawk, whip-poor-will, chuck-wills-widow and the poor-will. They are all small birds but their long wings and tails make them appear much larger than they really

are. The nighthawk, for example, whose body is smaller than that of the robin, appears, on the wing, about the size of a sparrow hawk. A few of the tropical woodland night-jars are considerably larger, about the size of short-eared owls, which, indeed, they somewhat resemble. Nor is it any wonder when we stop to consider the close relationship of the goatsuckers to the owls.

It is not only in color and nocturnal habits that the goatsuckers resemble the owls but structurally as well. So much so, in fact, that modern systematists remove the owls from the raptorial birds where they have rested for so long, and put them close to the goatsuckers. The principal differences between the two groups have arisen because of their differences in food habits. The owls are largely carnivorous and their bills and feet have been modified for catching mice. The goatsuckers, on the other hand, feed chiefly on flying insects and have little use for their bills and feet, so that these have degenerated while their mouths have developed to an extreme size. In all but the nighthawks, the corners of the mouths are provided with long bristles, making them most efficient scoop nets. The seven species of woodland night-jars (*Nyctibius*), however, have much heavier bills which are strongly hooked, and they have better developed toes. They differ also in assuming an erect, owl-like position when at rest and in having the eyes more nearly directed forward. Indeed, in many respects, they seem intermediate between the rest of the goatsuckers and the owls. The nighthawks and whip-poor-wills, when at rest, always perch lengthwise of the branch or log because of the weakness of their feet. This, together with their eyes being on the sides of the head, destroys their similarity to the owls in spite of the fact that their plumage is just as soft, their colors similarly mottled and their eyes much larger than in ordinary birds.

In nesting habits, the goatsuckers are at the bottom of the scale. They build no nest whatever but lay their eggs on the bare ground without even a depression to keep them from rolling. The North American species normally lay two eggs, but the tropical species but one. The eggs are

whitish or cream-colored, marked with darker gray and purplish, those of the nighthawk being quite inconspicuous on the gravel where they are usually laid, but those of other species being quite the reverse. The young are hatched blind and helpless but are soon covered with long grayish or brownish down not very different from that which covers young owls.

The most abundant and widespread of the goatsuckers is the nighthawk, which is found in summer in one or another of its sub-species from Florida to Alaska. In winter the nighthawk retires to South America, traveling in scattered flocks. Sometimes they just skim the ground or large bodies of water when, at a distance, they look remarkably like black terns. Again, they fly high overhead. In climbing the Andes of Colombia in October at an altitude of 12,000 feet, the writer once saw flocks of nighthawks flying several thousands of feet higher, crossing snow-capped ridges and making for the plains beyond. The birds that nest in Alaska have a long way to travel, for even should they stop in the Bahamas, it would mean 6000 miles each way, while if they continued to central Argentina, as do many, it would mean an annual pilgrimage covering at least 18,000 miles.

Nighthawks are usually birds of the pasture or prairie country and are seldom found in heavily wooded districts unless it be in clearings. They spend the day perched lengthwise on a rock or post or branch of a tree when they will frequently permit of a close approach. At dusk they begin hawking about after insects and consume great quantities of gnats, mosquitoes and other flying insects. Five hundred mosquitoes were found in the stomach of one nighthawk and eighteen hundred winged ants in another. Occasionally they pursue insects on bare ground and are sometimes seen at dusk along country roads, flitting from spot to spot capturing beetles and grasshoppers. Sixty grasshoppers were found in the stomach of one bird. They ordinarily feed only at dusk or at night but during the nesting season or on their migrations, they are sometimes seen darting about high overhead even on bright days.

In former years, the nighthawk was shot for sport in large numbers throughout the South where it was known as the "bull-bat". Its erratic flight made it a difficult mark for the gunners, and it was considered legitimate sport to go out at dusk and shoot them as they darted back and forth over the pastures after insects. Sometimes they were used as food. For a time they became extremely scarce and in some localities were threatened with extinction, but now that their value has come to be realized, and they are rigidly protected by both state and federal laws, shooting them has gone out of vogue, and they are increasing in number.

In recent years, the nighthawks have been attracted to large cities where the flat-topped buildings with their gravel roofs are not very different from the stony fields where the birds ordinarily nest. They have little competition from other birds for the host of flying insects that are attracted by the lights, and they are steadily increasing. They are often seen perched on chimneys or gables during the day and darting overhead at dusk uttering their sharp call of "peerd-peerd". During the breeding season they can often be seen to dive toward the earth from a considerable height, catching themselves with an upward turn just before they strike the house tops, the rush of the air through their wings causing a roaring sound like that produced by blowing over the bunghole of a barrel.

The nighthawk and the whip-poor-will are quite similar in appearance, both being beautifully mottled gray and brown, somewhat lighter below with conspicuous white patches on the throats and white in the tail. The nighthawks are easily distinguished by a white bar across the wing which is very conspicuous during flight. The two birds, however, are not ordinarily found in the same kind of places and their habits are quite different.

The whip-poor-will is a bird of the woodlands, spending the day on the ground under the trees and coming out into clearings or along the forest borders at night to feed. At such times it sometimes ventures close to door-yards and startles the unsuspecting householders by its loud liquid notes —

"whip - poor - will — whip - poor - will — whip-poor-will." They are given with an accent that does not tend to make one sorry for poor Will but rather to feel that he quite deserves all that is coming to him.

The whip-poor-wills feed upon larger insects than the nighthawks, being particularly fond of the large night-flying moths, the larvæ of which are very destructive to the foliage of trees.

Whip-poor-wills are found in summer from Florida to Nova Scotia as far west as the plains. They leave with the nighthawks for the South the last of September or the first of October, but they do not go as far, for they stop in Central America and the West Indies.



Photo by A. Dawes DuBois

ANOTHER CASE OF CAMOUFLAGE

The Western nighthawk on its eggs.

In the Gulf States and occasionally as far north as Maryland and Ohio, occurs the chuck-wills-widow which is a larger edition of the whip-poor-will. In habits it is not very different except that it is occasionally known to pursue and swallow such small birds as warblers and sparrows, and hummingbirds have been taken from their stomachs.

The whole family of goatsuckers is without exception one of the most beneficial that we have. An occasional small bird swallowed by the chuck-wills-widow is the only exception to a diet that is almost exclusively insectivorous. They capture the night-flying insects which have few other bird enemies and some of which are the most destructive that we have. Their weird calls and nocturnal habits will undoubtedly continue to prejudice unthinking people against them and we should, therefore, do everything in our power to disseminate the truth and cultivate a love and respect for them.

NEITHER TOO MUCH NOR TOO 'LITTLE



The Venus of Milo, physiologically and artistically considered the perfect woman, is an example of the results of proper nourishment — neither too much nor too little — on a nobly planned frame.

SOME PROBLEMS OF DIET

What We Should Eat and When
and How We Should Eat It

THE KIND OF FOODS NEEDED BY THE HUMAN BODY

THE pioneer settlers of this country had at least one great advantage over us: they were not embarrassed by the question, "What shall I eat?" They ate everything there was to eat, and because their bodies were very active, they probably ate with relish foods which we would scarcely care for. At the present time there are so many articles of food in the market, so many kinds of meat on the bill of fare, so many package and ready-to-serve foods in the shops, so many vegetables and fruits coming in fresh all the year round that the effect is bewildering. The selection of proper nourishment cannot be left to chance nor to the caprice of appetite. The matter really merits a little serious thought; for on the one hand it is literally possible to starve oneself (of important food constituents) in the midst of plenty, and on the other, it is not only possible but probable that, unless we give special attention to the matter, all of us will suffer in some way from eating too much.

In order to give an intelligent answer to the question *what* to eat one must give careful consideration to several underlying questions: (1) what is food; (2) what purpose is served by each kind; (3) where the essential constituents of a diet may be obtained; and (4) which combinations of these elements best fulfill the requirements.

The human body is a self-building, self-regulating, self-repairing engine. The gasoline engine gets its power from its fuel; the fuel is burned and its potential energy is transformed into mechanical power and heat. The body does the same. Food is oxidized and its latent energy is transformed into functional power and heat.

But no engine builds itself and keeps up repairs out of materials supplied for fuel as the body does; few engines can utilize so large a percentage of the fuel energy for useful forms of work; no engine can use its own substance for fuel when the supply runs short, or store up an excess of fuel in a form easily convertible into work and heat, for a colder day. All these things that marvel of mechanisms, the human body, can do.

Food is any substance which the body can make use of: (1) either to furnish material for its growth and repair; (2) to supply its energies; or (3) to regulate and harmonize the working of its parts.

The air is not usually thought of as food and yet one of its elements, oxygen, is the most important substance which the environment has to offer. A person can live without food thirty days, without water three days, without oxygen not more than three minutes. What the draft is to the furnace, the oxygen we breathe is to the human cells. Some cells of the body, as the muscle cells, utilize the energy which comes from oxidation to do external work, *i.e.* work in the sense in which an automobile does work. In so doing they produce a large amount of heat which the body uses to keep itself warm. Other cells, as the liver cells, produce a large amount of heat by oxidation without doing any external work. The work they do may be called by contrast "internal" work. It is work in the chemical rather than in the physical sense. This work is even more important than the physical work; for a thing may be alive without doing any external work, but nothing can remain alive for so long as half an hour without doing chemical work.

The heat resulting from these chemical changes is likewise used to keep the body at a certain definite temperature. In the next chapter we shall see how its production is very nicely adjusted to the needs by a regulating mechanism.

If we pursue this need for oxygen a little farther we learn that there is something beyond the need for physical energy (movement) and chemical energy (heat) — that merely to keep alive requires oxygen. For there are organisms which do not keep themselves warmer (plants, generally speaking, keep themselves colder) than the atmosphere or the water in which they live; and many, many organisms do not move of their own effort. But they nevertheless use oxygen — cannot live indeed without it. So it is with some cells of our bodies. They do no external work, they produce no heat and yet they require oxygen to keep alive. We may think of this need as the least dispensable of all, because the oxygen probably maintains the very structure which alone can manifest life.

The fuel foods

Let us now turn from the draft to the fuel itself. If we trace the foods which yield us most energy to their sources and inquire where that energy came from, we soon come back to the green plant and find that the energy of all living things is derived from the sun. Plant life has the advantage over animal life that it can make direct use of the sun's energy. Green plants contain a substance named "chlorophyll" which is, probably, the most potent substance in the world. Some poet should write an ode to chlorophyll, the mighty magician with the beautiful name, who transforms the giant energies of the solar furnace with less than a touch into food for the teeming billions not only of the human race, but of all animals of land, sea and air. This marvelous substance in the leaf simply gathers the sun's rays and focuses them, as a lens, upon the compound known as carbon dioxide, breathed into the leaf from the air. The focused energy pries loose the oxygen from the carbon and enables the latter to com-

bine with the water which comes up to the leaf from the root of the plant. Already this simple compound contains energy which can be set free by oxidation; but if we were to eat it as a food it would kill us, for it is none other than the deadly poison formaldehyde, which we use to kill germs. The magician is not through with it, however, for no sooner is it formed than it is at once tied up with five similar molecules to form sugar, and the sugar, carried to the seed or the root or the stem of the plant in the sap, is quickly transformed again into starch. As starch or as sugar we can make use of the material; for these are at once the cheapest forms of energy which we can buy and the most readily prepared for our cells. We can easily understand why this form of energy is not costly to man; for nearly all the labor which goes into the product is performed by the sun under the sorcery of chlorophyll. All man needs to do is to place the seed in the prepared ground, keep the weeds away and keep the soil cultivated, and the sun does the rest. A thoughtless farmer may be under the impression that he does the work. To get a fair notion of how much work he does, he need only compare the food energy which he consumes while tending the crop with the food energy which the crop can yield when it is harvested. One man's bodily energy is thus multiplied into the energy of a thousand. The agent is our magician chlorophyll, and the power comes straight from the sun.

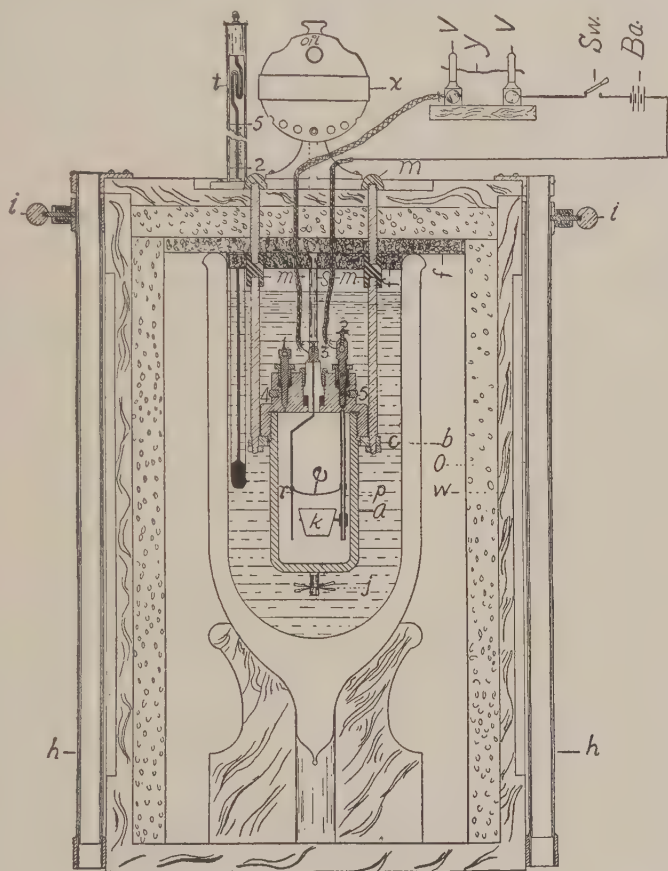
The plant makes the starch, of course, for its own use or the use of its offspring, the next generation. Starch stored in seeds like rice, corn, wheat, oats, beans, etc., is placed there to be of use when the young plant germinates. Starch placed in the apple, the banana, the potato and the carrot is for a similar purpose although it is not in the seed. One might think that plants would get tired after a while of making starch for their own offspring, seeing that so little of it is ever used for that purpose; but as a matter of fact, they get tired rather of making the seeds. Seedless oranges and grapes are examples to be seen at every fruit stand.

Some plants go still farther in the manufacture of energy-yielding foods for us. A good example is the olive tree. Not content with storing starch around the seed, it converts much of the starch to a very nutritious oil. Many nut-bearing plants do the same: the "nut" we are most fond of — the peanut (which is, strictly speaking, not a nut at all, but an underground bean) — is good for use, in moderate quantity, partly because of the oil it contains. These oils (olive oil, peanut oil, coconut oil, cotton-seed oil, etc.) are spoken of as "rich" foods because the energy in them is very concentrated. They cost us more in pure form than starch because more human energy must be expended to make them available to us. Animal fats have a similar energy value to that of the vegetable oils.

There is a very pretty way of telling exactly how much energy a food contains. Whatever we do with the energy we get from a food, aside from performing external work, whether we use it in grinding and digesting food, in driving the blood around, or in thinking, it finally takes the form of heat; even the work we do on external objects can be measured as heat.

Hence the best measure of the energy a food can yield — the measure which will cover every last trace of energy — is one expressed as heat. The starches and oils, — the energy-yielding foods, — when burned in the body, give up all of their heat, and this is exactly the amount they

will yield when burned outside of the body, provided the combustion is complete in both cases. Ordinarily we need take no special precautions to make it complete in our bodies, for our cells have that wonderful power which every automobile manufacturer would be glad to imitate if he could, of making the fuel burn without kindling or sparking. Outside the body, however, in order to make a food burn completely we must surround it with pure oxygen and then fire it with an electric spark. The heat given off



From *Journal of the American Chemical Society*

CALORIMETER (RICHE) TESTING HOW MUCH ENERGY A FOOD CONTAINS

The food is placed in *k* and is ignited by sending a known amount of current through *e*. *a*, Krock bomb; *b*, vacuum cup; *c*, split ring; *e*, platinum wire; *f*, felt; *h*, hole in inner tube; *j*, spring stop; *j*, stirrer; *k*, capsule; *m*, fiber; *o*, cork; *p*, platinum tube; *r*, platinum rod; *s*, stirrer rod; *t*, thermometer; *v*, fuse wire posts; *w*, wooden box; *x*, motor; *y*, fuse wire; *Sw*, switch; *Ba*, storage batteries; *1*, valve screw; *2*, valve screw; *3*, insulated post; *4*, inlet screw; *5*, inlet screw.

is caught in water and we tell how much heat there is by noting the rise in temperature of the water. If the amount of water is one liter (a little more than a quart), and the rise in temperature is one degree in the Centigrade scale, the amount of heat is said to be one calorie. Regulating the number of calories needed is simple when the term is understood.

The layman is inclined to be a little frightened by this term. We must remember that it means only "energy unit". Doubtless there have been good engineers who knew how to judge coal fairly well without burning it in a calorimeter, but no modern power engineer would neglect such an accurate means of finding out what he needs to know, namely, how much power he can get out of his coal. So also if you wish to know how much power you can get out of any food, you must know how many calories it will yield to your body. We make no claim that this is all you need to know about food. That we shall see as we proceed.

All the foods available in our wonderfully varied markets in this country have been tested many times and the heat values have been tabulated, so that any housewife, or any other person interested, can find out whether the money will go farthest in buying energy if spent for potatoes, or for rice, and so on.

It makes little difference to the body which of the two kinds of food we have thus far been talking about you give to it; only this we must remember: a given weight (pound, ounce or gram) of oil or fat will, if pure, give us more than twice as much energy as the same weight in either starch or sugar of any kind. A pound of starch will yield about 1850 calories; a pound of pure olive oil 4200 calories. A man can eat food consisting mainly of starches and sugars and very little oil and get his energy from them, or he can eat foods which produce oil or fat abundantly and get his energy from them, or he can mix the two and get along. There is doubtless a *best* proportion of these two classes, fats and carbohydrates, but it is certainly not the same for all. Persons doing heavy muscular work find that the muscular effort can be made with greater ease and comfort to the worker if there is plenty of carbohydrate in the diet, while for persons of sedentary habits too much carbohydrate easily produces fermentation in the stomach and may lead to overstrain on some organ. The fats should never be entirely excluded; for besides giving energy in its most con-

centrated form and serving therefore to keep down the bulk of food which one must put into the stomach, they serve also as a solvent of certain important constituents which will be mentioned later.

Carbohydrates are most readily prepared for absorption and are most readily burned of all our foods; an excess can, as a rule, be converted to fat and stored against a time of greater need for energy.

In general a person would be on safe ground if he were to take one-fourth of his energy in the form of fat and three-fourths in the form of carbohydrate or carbohydrate-yielding substances.

Not less than three-fourths of all the food we eat goes for the purpose of supplying energy and nothing else. For the laboring man the proportion is greater.

The building and repair foods

Now we come to another kind of foods, namely, those which are necessary for building and repair. The most important is the great class known as "proteins". They constitute the very sinew of life. The most familiar members of this class are of animal origin: lean meat, fish, milk, eggs. Vegetable proteins are furnished by peas, beans, lentils, nuts, etc., yielding highest percentages, the cereals yielding moderate amounts, and the succulent vegetables and fruits coming last.

All the foods which supply energy contain carbon, hydrogen and oxygen; but protein alone supplies nitrogen, without which neither growth nor repair can take place.

Proteins separated in pure form have the general appearance and properties of white of egg. They are built up of varying combinations of eighteen simpler substances containing nitrogen, called "amino acids". A certain group of them, as the proteins of milk, meat, egg, use all these amino acids and are called "complete" proteins. In certain others, such as gelatin and some of those produced by plants, certain important amino acids are wanting; they are therefore called "incomplete" proteins.

Professor Graham Lusk has suggested that the former group should be desig-

nated "Proteins of grade A"; the latter "Proteins of grade D". Grades B and C would constitute mixtures of complete and incomplete proteins in different proportions such as occur, for example, in wheat (B) and corn (C) respectively. Such a designation on the label of package foods, if required by law, would enable the purchaser to know what protein value he was buying. Only proteins of grade A can replace body protein part for part. Proteins of grade D have almost no value in this respect and proteins of grades B and C are adequate only because an incomplete protein is supplemented by a complete one in the same plant. The incomplete proteins will not support growth. This has been demonstrated conclusively for certain animals and is undoubtedly true for children.

This division of our subject is so important from the standpoint of those who are responsible for the choice of foods for the family that we must look into it a

little farther. After the discovery by Emil Fischer that proteins are made up of nothing but amino acids, Hopkins in England instituted the first experiments designed to ascertain which of the amino acids are essential. Feeding young rats with zein, one of the proteins found in Indian corn, as the only nitrogenous constituent of the food, Hopkins found that the animals would survive for only a short period. The reason, as it soon developed, was that this protein lacks two of the eighteen amino acids. When one of these, which has the rather formidable name of "tryptophane", was added the rats survived for a much longer time, but still did not grow satisfactorily. The diet became only what one would call a "maintenance" diet. In this country it has since been shown by Osborne and Mendel that when the other amino acid lacking from zein, "lysine" by name, was added in addition to the tryptophane, growth became normal.

The comparable photographs of Rat 2161 from Mendel and Osborne, *Journal of Biological Chemistry*, show the animal (below) at the age of 246 days and 71.5 gm. body weight after a prolonged suppression of growth on a diet in which the essential nitrogenous component consisted of the protein zein with the addition of tryptophane and lysine in small amounts.



Growth was resumed at the age of 248 days on a diet in which zein and the amino-acids were replaced by casein. The upper photograph shows the same rat at the age of 459 days with a body weight of 295 gm. The photographs were made under exactly comparable conditions with respect to focal distance, apparatus, etc.

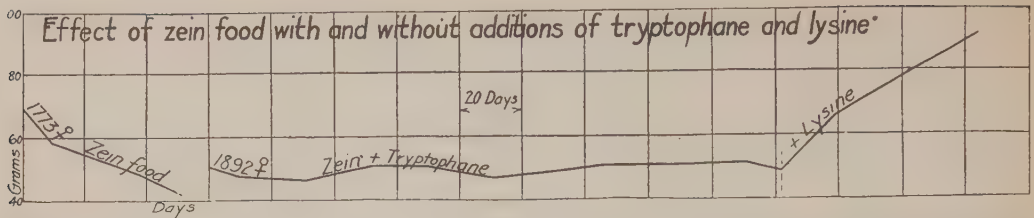


Chart showing nutritive decline on zein food, maintenance after addition of tryptophane, growth after addition of both tryptophane and lysine. Rat 1892 was maintained during one-half year without significant change in body weight on the zein + tryptophane food. Despite this inadequate diet the capacity to grow was not lost at the end of this prolonged period, and the animal ultimately grew to full adult size on a mixed diet.

These were the beginnings of much important work looking to the establishment of the correct nutritional value for the different proteins. Osborne and Mendel are now able to state definitely that adequate growth can be fostered with albumin of milk, albumin of eggs (also the characteristic protein of the yolk), with glutenin of wheat, glutenin of corn and so forth. All of these therefore may be called "adequate" proteins. It is interesting to note that many grains which produce an incomplete protein, such as wheat with its gliadin, corn with its zein, make up for the deficiency by producing along with it a complete protein. The same is true of milk; for casein, which makes up the bulkier protein of cow's milk, is inadequate alone to support growth, whereas the albumin of milk—the protein which forms the "skin" when milk is boiled—is quite adequate. Mother's milk, we may note in passing, is much richer in this protein than is cow's milk. It turns out that foods designed by nature as a source of building material in the young, eggs and milk, are rich in the two essential amino acids tryptophane and lysine.

The processes of digestion and assimilation separate the individual units of protein and rearrange them into body protein in a manner similar to that of tearing down an old house and using the stones to build a new one. All of the building stones must be cleaned and many must be reshaped to be fit for use in the new structure. Digestion may be said to be the reduction of food substances to their simplest elements; the digestion of proteins is the process of reducing them again to their amino acids. In the words of Lusk, "These amino acids may be com-

pared to the letters of the alphabet. When they are arranged together they can make many different proteins just as there are many words in the dictionary. For example, suppose the word 'albumin' were broken up by digestion into the letters, *a, b, i, l, m, n, u*; these letters absorbed could be reconstructed into albumin again. The same may be said to be true for the word 'globulin.' Now if both albumin and globulin were to be formed from a common word, one would have to eat a hypothetical substance called 'am-globulin', convertible into globulin if the letters *a, m* are abandoned to their fate, or into albumin on neglecting the letters *l* and *g*. Carrying the analogy still further it is evident that if the letter *b* were not in the word 'am-globulin', neither albumin nor globulin could possibly be produced. Incomplete proteins, *e.g.* many plant proteins and gelatin, lack some important amino acid,—just as the hypothetical word might lack *b*. They alone cannot be reconstructed into body protein. Some other food must be added to supply these lacking units."

Fortunately for our general health most protein foods contain so good an assortment of amino acids that an adult on ordinary mixed diet need have no concern as to the kind of protein he is eating. But in choosing a diet for growing children it becomes a matter of importance.

Various plant proteins are eaten by cattle and sheep, one kind supplying the units lacking in another, and when the animals have eliminated the units not necessary for the structure of their own body cells, the animal protein has acquired a higher food value than that possessed by any single vegetable protein.

"The body of an average man weighing 156 pounds contains 30 of protein, or 20 per cent of the live weight. If a man starves he will lose five parts per thousand of his protein store daily. If he be given fat and carbohydrate in large quantity, the daily loss of protein may be reduced to 2.5 parts per thousand. This loss of body protein represents the irreducible minimum of wear and tear on the constituent parts of the machinery of the cells." This minimal loss of protein cannot be prevented by giving gelatin, as has been demonstrated by experiment (nor indeed by any other incomplete protein) with the fats and carbohydrates. But if protein in the form of beef, in quantity equal to the irreducible minimum of wear and tear, be added to the diet of fat, carbohydrate and gelatin, the waste of body protein stops at once. Wheat proteins were found to be far less efficient than beef in protecting the body from protein loss.

Experiments by Thomas have demonstrated the relative biological value of different proteins. The following are the least daily amounts which will protect the body from protein loss: meat protein, 30 grams; milk protein, 31 grams; rice protein, 34 grams; potato protein, 38 grams; bean protein, 54 grams; bread protein, 76 grams; Indian corn protein, 102 grams. When we recall that only 7.5 per cent of bread is protein and only 4 per cent of corn meal, it will be seen that to get a sufficient quantity of protein from these latter would require a very inconvenient amount to be eaten in one day.

"Protein is usually taken in excess of that bare requirement which is measured by the quantity necessary to repair the tissue. This excess is oxidized and used for fuel just as are fat and carbohydrates. Protein has one property out of all proportion to that possessed by other food-stuffs; it very largely increases the production of heat in the body. Persons maintained on a low protein diet may suffer intensely from the cold. One may cause the heat production of a dog to double by giving it three pounds of meat. This heat-increasing property of protein is called its "specific dynamic action."

It is well to emphasize that while protein is absolutely necessary to maintain tissue in repair, to promote growth, and to stimulate heat production, it is not economical as fuel. Nearly all the food we eat is for fuel, and the cheapest fuel is carbohydrate, and after it fat. In starvation the carbohydrate reserve is burned first, fat second, and the protein as a last resort, showing that the body knows how to protect itself against the loss of this most precious material and takes steps accordingly.

Salt-like foods

Besides nitrogen, proteins form the main source of two other important elements, namely, sulphur and phosphorus. Sulphur is needed especially for such structures as hair and nails; in combination with calcium, phosphorus is especially needed for the bones. Both enter also into the composition of living protoplasm throughout the body.

Both these elements are supplied to the body to some extent also in the form of salts. Both are present in this form in meat, and the acid radical here being in excess of the basic radical the ash of meat is acid in reaction. It is important to bear this in mind; for when digestion takes place and the protein of the meat is absorbed, this acid ash is set free and is absorbed along with the protein. An excess of meat therefore always produces a strongly acid urine for the reason that these acids must be removed as rapidly as they are formed. There is danger, however, from excessive meat eating that the acid will not be removed fast enough.

Most vegetables and fruits, even those which taste acid, contain a basic ash and if plenty of vegetables like potatoes, carrots, beets, turnips, cabbage, etc., are eaten with the meat, the surplus of acid is neutralized. Under these conditions uric acid will be readily dissolved and removed from the system and any tendency to gout will be counteracted. Milk yields an almost neutral ash. Most cereals yield an acid ash, but the acidity is much less than that of meat. The ash of rice is more acid than that of potatoes.

Iron is another essential mineral element. A person lacking the requisite number of red blood corpuscles or the required percentage of iron therein is said to be "anemic", and this lack must quickly be supplied. Very small quantities are needed, but they are absolutely essential. It is found in many foods, especially in egg yolk, spinach, string beans, cabbage and lean beef.

Calcium is necessary for the formation of strong bones and teeth. Cow's milk is the food richest in calcium, being 24 times as valuable for that element as white bread and meat. It may be obtained from wheat and other grains if the entire outer coat is used, as in whole-wheat bread, and from many vegetables, as cauliflower, celery, spinach, cabbage and carrots.

The nice balance between the functions of the various glands, between the muscles and the nerves, between the composition of the blood and the action of the heart is all maintained by means of the presence of chlorine, calcium, magnesium, sodium and potassium, held in solution in the proper proportion. These elements are grouped together and called "salts" or "mineral matter" or "ash constituents", because they are left behind as ashes when the food is burned. The relative amounts of these different elements in the adult body is shown in the following table.

AVERAGE ELEMENTARY COMPOSITION OF THE HUMAN BODY

Oxygen, about	65.0	per cent
Carbon, about	18.0	per cent
Hydrogen, about	10.0	per cent
Nitrogen	10.0	per cent
Calcium, about	2.0	per cent
Phosphorus, about	1.0	per cent
Potassium, about	0.35	per cent
Sulphur, about	0.25	per cent
Sodium, about	0.15	per cent
Chlorine	0.15	per cent
Magnesium, about	0.05	per cent
Iron, about	0.004	per cent
Iodine	} very minute quantities	
Fluorine		
Silicon		

Vitamins

In addition to all the foods discussed there are minute quantities of other substances whose nature is not yet demonstrated, but which have a profound influence upon nutrition. Some physiologists call them "vitamins", some "accessory substances" or "food hormones". It has been shown by experiment that a strictly pure diet of carbohydrates, fat and protein, with proper proportion of ash, will not cause animals to grow unless some unrefined natural food is added. People living entirely on polished rice as a source of vegetable matter develop a disease known as "beri-beri", which can be cured by adding the brown husk or coating of the rice grain lost in the polishing process. People who live too largely on refined corn meal and fat meat are often attacked by a kindred nutritional disease called "pellagra", which may be cured by adding meat, milk or eggs to the diet. Sailors on a long voyage often develop scurvy, but usually recover when allowed to eat freely of fresh vegetables. Babies fed on boiled milk or prepared food must occasionally have orange juice or fresh milk for a similar reason.

Under ordinary conditions there is little danger of any of these diseases. It is interesting to know that even savage people intuitively supply these accessory substances in some form. Captain Cook, the explorer, avoided scurvy on his second voyage, although it lasted 1000 days. He says: "We came to few places where either the art of man or nature did not afford some sort of refreshment, either of the animal or vegetable kind. It was my first care to procure what could be met with and oblige our people to make use thereof, both by my example and authority; but the benefits became so obvious that I had little occasion to employ the one or the other."

It is therefore important not only to estimate the value of the diet in calories and its content of carbohydrate, fat and protein, but to see that this small quantity of "accessory factors" or "vitamins" is present.

Each constituent has a special function. One stands a much better chance of finding an efficient occupant for each place if there are a large number of applicants. Some day we shall know the qualifications of each constituent and shall be able to choose more intelligently.

This brings us to the subject of vegetarianism. Many people have convinced themselves that clear thinking and right living are only attainable by subsistence upon products of the vegetable kingdom, although many who call themselves "vegetarians" partake of milk, butter and eggs. From the scientific—that is, common sense—standpoint, there is only one objection which can be fairly urged against the inclusion of meats in the dietary, and that is, they are too easily digested. It sounds paradoxical to speak of a food as being too readily digested, but in the case of meats that is literally true, even when they are not thoroughly cooked. When stomach digestion is good, meats are very rapidly resolved into products which can enter the blood. If these products reach the blood in larger quantities than needed for repair, they are taken to the liver and are split up, a portion being worked over into urea for excretion by the kidneys, and another portion stored or burned. If the quantity eaten is large, the work of removing the surplus may be considerable, and in time may overtax the organs concerned. The rational thing to do, therefore, is to eat meats very moderately. With this precaution enforced there is no good reason why so valuable an article of diet should be stricken from the list of advisable foods. On the contrary there is good reason for believing that a certain stimulating effect is obtained from meats which is obtainable from no other source.

Because meats are too readily digested, and therefore too completely absorbed into the blood, leaving too little residue to be voided, they tend to produce constipation. The same may be said of white bread and milk. When any of these are eaten there should always be some coarse food, which is not so readily digested, taken with them. Nothing interferes with clear thinking more than constipation.

Digestibility

In general it may be said that most foods are more completely digested than is commonly supposed. Some, however, contain a considerable proportion of insoluble material. For example, the outer hull of the wheat grain contains woody substance which resists the action of the digestive ferments in the human alimentary canal, though a large part of it can be assimilated by cows and sheep. It is not without value as ballast in man's dietary, however, for too finely milled grains are largely responsible for a tendency to constipation.

In the total food of an ordinary diet, according to Atwater, about 92 per cent of the protein, 95 of the fat, and 97 of the carbohydrates is retained in the body. In the average proportions in which different animal and vegetable foods are combined in the diet, about 97 per cent of the protein, 95 of the fat and 98 of the carbohydrates of animal food is digested, while only 84 per cent of the protein, 90 of the fat, and 97 of the carbohydrates of vegetable foods is digested. Animal foods therefore have a greater digestibility than vegetable, especially as regards the protein they contain. Of two cereals containing about the same amount of dry matter, but with different proportions of protein and carbohydrates, the one with the larger proportion of the less digestible protein and the smaller proportion of the more digestible carbohydrates will be, on the whole, less completely digested.

KIND OF FOOD	DIGESTIBILITY PER CENT		
	Protein	Fat	Carbohydrate
Meat and fish	97	95	98
Eggs	97	95	98
Dairy products	97	95	98
Animal food of			
mixed diet	97	95	98
Cereals	85	90	98
Legumes (dried)	78	90	97
Sugars			98
Starches			98
Vegetables	83	90	95
Fruits	85	90	90
Vegetable food of			
mixed diet	84	90	97
Total food of			
mixed diet	92	95	97

Summary

To sum up, we learn that the complete needs of the body are embraced in six classes of substances named in the order of their importance: (1) oxygen, which is the only constituent of the air that we can use; (2) water in sufficient quantity to dissolve the wastes; (3) carbohydrates and fats, which serve mainly as fuel and only to a slight degree as building material; (4) proteins, the main structural material (in excess of the requirement for this purpose they also can yield energy); (5) salts, which are indispensable in the maintenance of the functional parts; and (6) the vitamins, which are essential in a regulatory capacity.

A dietary cannot be called well balanced unless it contains all of these. Oxygen as the basis of combustion we get almost wholly from the air, to a very slight extent from oxygen-rich foods such as sugars when these are being changed to fats; carbohydrates we get mainly from cereal foods in the form of bread, cakes, crackers, pie-crust, breakfast foods, rice, etc.; to a lesser extent from tubers and roots such as potatoes, carrots, beets, and from pod-bearing plants like peas, beans, lentils, peanuts, etc. Carbohydrates in the form of pure sugars, cane sugar, glucose, the basis of most candies, and much syrup,

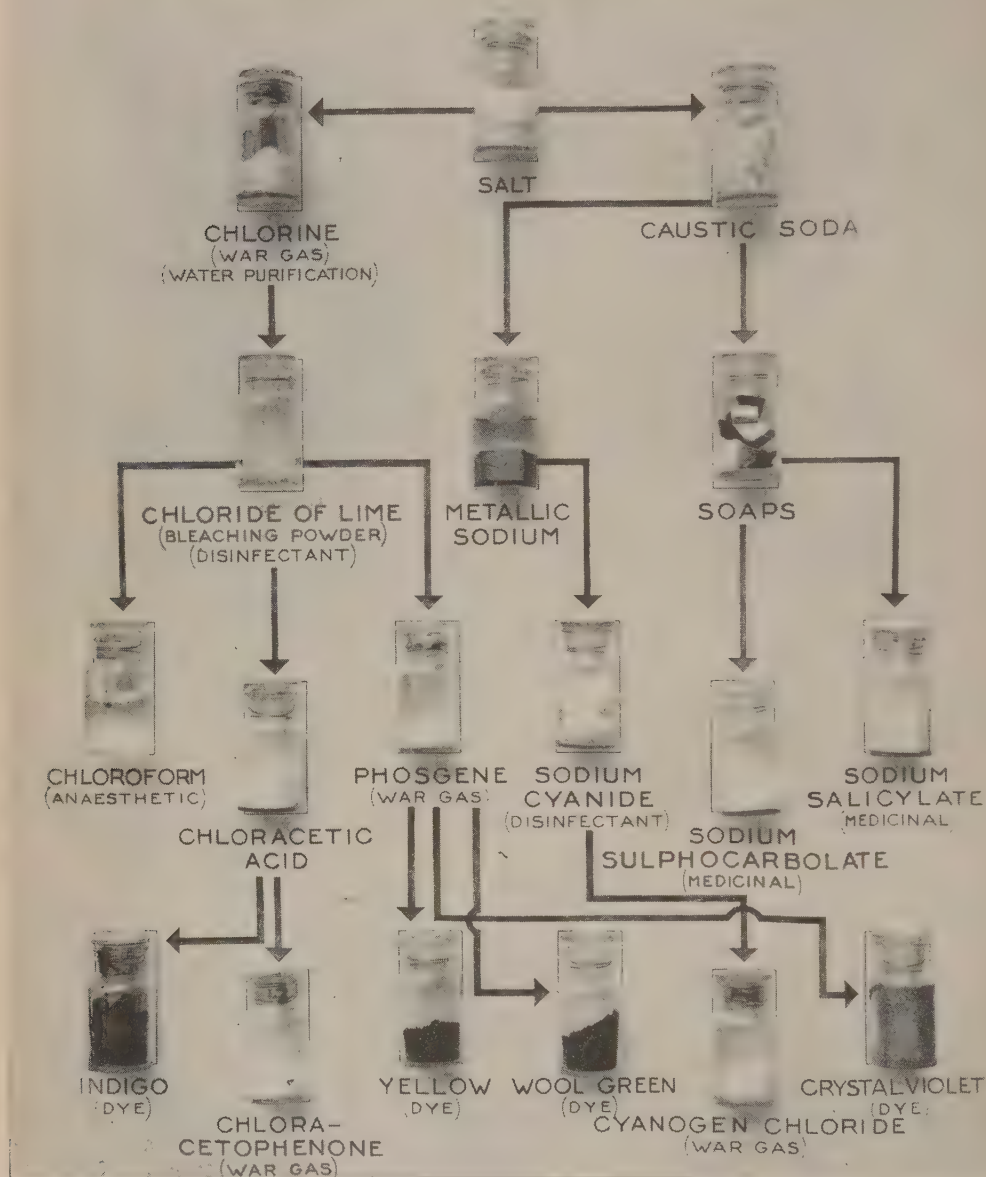
levulose from honey, etc., should always be taken very sparingly. The only carbohydrate of any consequence from animal sources is the sugar found in milk. Fats can be obtained from either animal or vegetable sources. The most valuable of all, doubtless, is butter fat. It contains important growth-promoting qualities quite aside from its fuel value. After it come lard, mutton fat, beef fat and the vegetable oils. The most valuable proteins are those of milk, eggs and meat, including fish. Next after these animal proteins come those which will support the meat-producing animals, namely, wheat, corn, oats, potatoes, peas, beans and nuts, and the like. Salts form an important part of all foods. Highly milled cereals, the "finest" grade flours, corn meal and polished rice are deficient in important salts; whole grain should be used. The ash from meats is acid, that from vegetables, even those which taste acid, is alkaline. Hence potatoes, carrots or the like should be used to neutralize the acid ash of meats. Vitamins are obtained in all fresh vegetables, from milk, eggs and meat. Examples of the proper proportions of the various food articles which should be eaten to yield these constituents in sufficient amount will be given in the next chapter, after considering the energy needs in some detail.



UNDERFED DERELICTS WAITING FOR THE BREAD-LINE

SALT PRODUCTS

IN WAR AND PEACE TIME INDUSTRIES



Courtesy National Research Council

SALT PRODUCTS

The two main products of salt are chlorine and caustic soda, which are obtained by the electrolytic decomposition of brine (salt solution). Just a few of the products obtained from these and their use are indicated on the chart. One does not always associate the production of a deadly war gas with the extraction of gold or the manufacture of soap, but the arrows show the relation. Then, too, few people may think that the same chlorine which was one of the principal materials required in the war gas program has also wide use in drinking water purification and by various treatments gives us such important products as chloroform and synthetic indigo.

The other illustrations in this chapter, except those on pages 3371, 3375 and 3376, are from Fries & West's "Chemical Warfare."

CHEMICAL WARFARE

Some of the Lessons the Great
War Should have Taught Us

PREPAREDNESS THE BEST PREVENTIVE OF WAR

A SURVEY of the rôle played by chemicals in the Great War reveals an interesting story, not altogether pleasant in some of its details, of the application of modern science to methods of destruction of life. It is the story of the sudden realization of the possibilities of chemical warfare, with its gas of the asphyxiating, tear-producing and sneezing varieties, with its toxic smokes, liquid fires, etc.; of the almost overnight mobilization of the chemical brains of the Allies to understand and counteract this new phase of German frightfulness, and of the successful building up of a Chemical Warfare Service in the United States and abroad which eventually succeeded in giving the latter a liberal and effective taste of his own medicine.

The use of poison gases for attack by no means originated with the late war. As far back as 431 B.C. the Spartans saturated wood with pitch and sulphur and burned it to asphyxiate the enemy. Later incendiary arrows were employed and chemicals were used by the Greeks in their "fire". Even during our own Civil War the fumes of burning sulphur were utilized to suffocate and smoke out the opposing side. Gas warfare, then, is not new and its gradual development has kept pace with chemical knowledge much as other kinds of warfare have followed the technical advance of the times. By the term "gas" in warfare is meant materials which cause injury when carried to the enemy along with the air. The term does not indicate the original condition, before being released, of the material present in shells, bombs or cylinders. In nearly

every case the "gases" are really liquids or solids, and when the containers are broken open they are volatilized, either by the gas pressure generated or by the force of the explosion. In general they are of three kinds: persistent, non-persistent and irritant. Another important group of materials used in chemical warfare is the so-called "smokes", which may be either poisonous or for screening the movements of troops from the enemy.

Poison gas was first used in the recent war on April 22, 1915, when the Germans employed chlorine from cylinders against the French and British lines in the Ypres salient. Previous warning of their intention was given the Allies by a deserter, but the possibility that the Germans would thus violate the Hague rules of warfare had not been given serious consideration, nor had any preparations for protection against it been made. Auld, in his "Gas and Flame", describes the results as follows:

"Try to imagine, if you can, the feelings and the condition of the colored troops as they saw the vast cloud of greenish yellow gas spring out of the ground and slowly move down wind towards them, the vapor clinging to the earth, seeking out every hole and hollow and filling the trenches and shell holes as it came. First wonder, then fear, then, as the first fringes of the cloud enveloped them and left them choking and agonized in the fight for breath — panic. Those who could move, broke and ran, trying, generally in vain, to outstrip the cloud which followed inexorably after them."

The development of the gas mask from the crude pad soaked in solution

Although the nature of the gas used was at first unknown, it was easily identified as chlorine, an elementary gaseous substance contained in common salt. The military authorities then consulted with the chemists and temporary masks were devised, consisting of pads of cloth soaked with various solutions, which when fastened over the nose and mouth afforded some measure of protection in the field. From this crude type the later more effective models were developed. The basic part of the mask was a metal canister of chemical fillings capable of completely absorbing from the air inhaled by the soldier the various types of gas encountered in the field. The grains of the filling material had to be of a size to present proper absorbent surface to the gas without offering too great resistance to breathing, and the stability of the materials, the hardness of the granules, their tendency to cake, and the over-all efficiency of the absorbents against mixtures of gases, had to be considered. With the introduction of new gases, especially tear gas, modifications in both nature and type of absorbents were made and the various chemical smokes, consisting of minute solid particles atomized through the air, required the use of ultra-microscopes to determine their physical nature in order to devise effective means of stopping them in the canister. Filter pads, first of cotton, later of felt, were instrumental in cutting down the penetration of smoke into the mask. Physiologists were consulted in order to secure a shape of face piece which would conform to the outlines of the face and yet fit so closely as to prevent leakage of gas. Studies were made of men wearing various types of masks while performing different kinds of labor, in order to determine their effect on the fighting efficiency of the soldier. It was found necessary to eliminate the mouthpiece and nose clip, characteristic of the earlier types, in order to secure the maximum of comfort for the soldier who must often wear a mask continuously for hours.

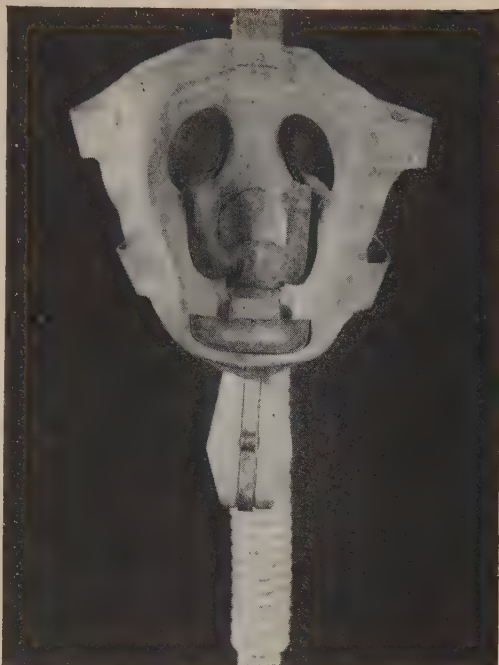
Great care was necessary in order to have the whole mask, face piece, canister and the connecting rubber hose, absolutely impermeable to gas, since a very small leakage of a highly toxic material may easily be fatal. At first anti-dimming compounds were spread on the eyepieces in order to prevent the collection of moisture thereon caused by the wearer's breath, but later the result was found to be more satisfactorily accomplished by carrying the exhaled air directly across the eyepieces, as seen in the Tissot mask.

There still remained the problem of how to make a mask which could be quickly and accurately adjusted at a moment's notice immediately the gas alarm was given and before any ill effects could result. Strange as it may seem, although the soldiers realized to a large degree the dangerous nature of the gas used against them and the necessity for holding their breaths and putting on the masks as quickly as possible, it was one of the most difficult tasks of the gas officer to train them so that they would adjust the mask and keep it on while in a gassed area. The penalty of failure to conform to necessary regulations in this respect was made very severe since it was almost certain to result in disability.

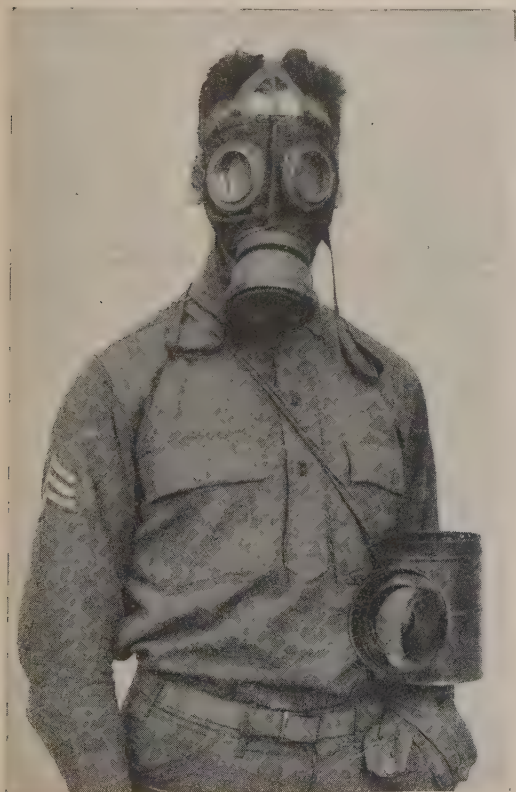
Following the first surprise attack in April, no gas was used by the Germans in the summer and autumn of 1915, and, fortunately, the Allies were able to develop methods of defense before the next attack, which came on December 19th, bringing with it the introduction of a new gas, phosgene, the particularly insidious action of which is due to the fact that a person may be only slightly gassed and apparently in good condition, but upon exercising is liable to suffer very serious effects and even die. Although the attack lasted less than an hour, it was necessary to use gas helmets for some time afterward on account of the persistence of the gas in the dugouts.

Discipline, in general, was extremely good and casualties, which were remarkably few, resulted primarily from a failure to observe carefully the necessary defensive measures.

AMERICAN AND GERMAN GAS MASKS



EXTERIOR AND INTERIOR OF AMERICAN TISSOT MASK



FRONT AND SIDE VIEW OF GERMAN RESPIRATOR

This second use of gas was particularly important because it brought out many principles on which future developments of the gas cloud attack were based. These were (1) increased concentration obtained by reduction in time occupied by the attack, (2) the use of the new material, phosgene, and (3) the element of surprise. The last was accomplished by making the attack in the dark of early morning when the Allies were less prepared and when better wind conditions prevailed. It was almost impossible to see any evidence of gas, and it could be

as other more poisonous gases, and were able to inflict quite a number of casualties. The Allies began to realize the extent to which the enemy were planning to push gas warfare, and a marked impetus was given to various protective measures.

This was the biggest year for German gas activity, five large cloud gas attacks being made against the British, several against the French and against the Russians. New features of these attacks were the use of a higher concentration of gas and an employment of a larger amount of the more poisonous phosgene. The newer



TOXIC SMOKE CLOUD FROM 500 D.M. CANDLES

The candles were placed in 5 parallel rows which were 2 yards apart, each row containing 100 candles on a 100 yard front. The total time of active smoke emission was 23 minutes.

detected only by the hissing sound of its escaping from the cylinders and by the odor. From this time on practically all gas attacks were made at night.

Some gas was undoubtedly used in shells in both the major attacks of 1915. The presence of xylol bromide was also detected about this time. This substance produces a copious flow of tears, even when present in such small quantities as one part per million of air by volume. It has no permanent effect, merely serving to put men temporarily out of action. In 1916 the Germans used a new lachrymator, as well

tactics employed were extra precautions in the way of secrecy in preparation, the use of smoke clouds to divert attention and the launching at varying intervals of a number of different waves of gas. This was particularly effective, since a second wave coming after the lull following the first often caught the men unawares.

The last German gas cloud employed against the British was in August, 1916. Here a very strong cloud of high phosgene content was launched during a relief period, thus coming at a time when practically double the ordinary number of

TWO OF THE NEW TERRORS OF WARFARE



Photos Kadel & Herbert, N. Y.

FRENCH GAS ATTACK AS SEEN FROM AN AIRPLANE
GERMAN LIQUID FIRE ATTACK

troops were in the trenches. It was so severe that gas helmets were needed for nine miles back of the point of discharge. Use of the gas cloud was abandoned on account of the limited number of gases which could be thus used, the limited number of cylinders possible to discharge at once, the difficulty of springing a surprise attack on account of labor and time in preparation, and because the highest concentration of gas usually occurred near the trenches of the side using it.



IMPERVIOUS OVERALL SUIT
For protection against mustard gas.

Use of the gas shell increased rapidly due to the fact that no limitations are inherent to the size and number of projectiles used or the variety of gas employed. Their use also makes it much easier to catch the enemy napping. Care had to be taken to prevent excessive casualties in the dugouts, where the persistent nature of gas was particularly evident, by using protective blankets, special alarm systems, rapidity in adjusting mask (6 seconds), and special methods for clearing out the gas.

An unusual night attack occurred in December, 1916, at Arras. An exceptionally large number of shells was fired, practically saturating the walls and floors of the houses and the adjacent fields. The weather was cold and the evaporation of the gas slow. The day following, when it had apparently been dissipated, many masks were discarded, but on account of the increased evaporation brought about by the warmth of the sun, a large number of men were gassed.

The use of mustard gas was undoubtedly the greatest single development of gas warfare during the great struggle, and marked a radical departure from the early idea that a material, in order to be effective, must have a very high vapor pressure, or, in other words, high escaping tendency. Mustard gas is really a liquid, boiling at 220° C. and has a very low vapor pressure. It is, however, very persistent, has a peculiar property of blistering the skin, and the vapor, when present in even minute concentrations, produces burns which require a very long time to heal. It was by far the most effective and deadly war gas used. At Nieuport, more than 50,000 shells were fired in one night and the town was practically deluged with it. During ten days in the autumn of 1917 it is estimated that over one million shells were fired containing about 2500 tons of it. From 1917 a very large amount of the time spent by the Allies on gas warfare was devoted to devising protective methods, such as clothing, gloves, helmets, boots and ointments, against this gas, and to efforts for manufacturing it in large quantities. It is certain that in future warfare, mustard gas will play an extremely important part and new and effective methods of utilizing it from airplanes etc., will be evolved.

"Lewisite," an arsenic derivative, another powerful toxic, was developed in connection with the studies on mustard gas. It is a strong vesicant and, although less persistent than mustard, is very effective in minute quantities. It has been reported that since the war the Germans and the Japanese have made extraordinary advances with this material.

Another substance of much tactical value was the so-called "sneezing-gas". This was diphenylchlorarsine, a solid which is atomized into fine particles on the bursting of the shell container. Innocuous "camouflage gases", from the mild to the vile smelling, were used to some extent and offer a great field for development in the future. They keep the enemy guessing as to just when it is really necessary to put on the mask and they can be mixed easily with or followed by toxic gases and so secure quite a few casualties.

Various types of incendiary materials were rather successful, particularly at first. The use of a portable tank, containing two compartments, one holding compressed nitrogen and the other oil, was early made by the Germans to produce the terrifying "liquid fire". This was discarded later as it was not effective for distances of more than 50 to 60 feet. The ends of the flame were apt to curl upward in the air currents, allowing the opposing side some protection when in the trenches, and it only lasted about a minute, after which time the flame thrower was absolutely at the mercy of the enemy. Although very effective at first in breaking down the morale of troops, it proved one of the great failures of "frightfulness".

A comprehensive organization was necessary to cope with the problems of chemical warfare and toward the end of the war it grew to be very complete. The United States is under particular obligations to the Allies for the information placed at its disposal during the early days of the conflict, by use of which it was possible to avoid many costly mistakes and to eventually assist them in the cooperative development of all phases of gas warfare. Extensive gas services were maintained particularly by the British, French and the United States both in the field and behind the lines, and the majority of the chemists of these nations were busily at work on chemical warfare problems. Various individuals, manufacturing plants and universities gave freely of their time.

Whenever a new gas was suspected as having been used by the enemy, scouts from the gas service would locate unex-

ploded shells and send them to the field laboratory of the Chemical Warfare Service, where the contents were analyzed. An intensive study was then made to determine the protection afforded by the mask then in use against this particular new gas. Wherever possible emergency problems were investigated near the field of action, but on account of the limited number of the technical staff abroad avail-



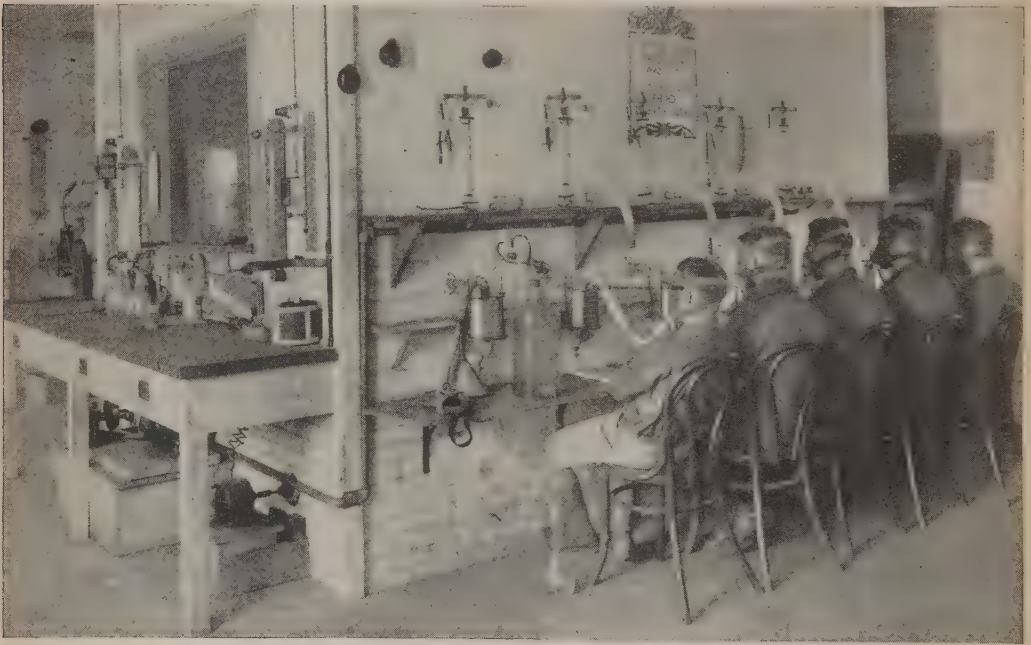
PROTECTIVE GAS OUTFIT FOR CAVALRY

Consisting of gas mask, gas suit, gloves and boots for man, and mask, boots and hoof pads for horse.

able, many of these problems had to be referred home. A suitable apparatus was erected from which could be obtained a stream of air charged with a definite amount per unit of volume of the gas previously prepared in the laboratory and of a known degree of purity. Methods of analysis for the amount of gas contained in a given amount of air were also necessary and were often rather difficult to develop quickly.

A so-called "tube test" indicated the relative efficiency of various absorbents for stopping the new gas. This consisted, briefly, in conducting a known volume of air containing a definite amount of gas through a definite layer of absorbent to be tested, analyzing the effluent stream of air at various intervals and determining thereby the time when the first traces of gas penetrated the absorbent layer. It was thus possible to obtain comparative data on different absorbents and on different gases and to set satisfactory standards to meet individual cases. Tests with

mined by the irritation caused when the gas penetrated the canister filling. When the concentration of the gas which would cause toxic effects had been determined by the medical department, a comparison was made with the concentration probably present under average conditions on the battlefield at given points, and the effectiveness of the gas arrived at. If the gas was of the tear or sneeze variety, the sensitivity of the soldier to such was ascertained. A study was also made of the comparative susceptibility of different men to gas with a view to removing from the



MAN TEST LABORATORY, AMERICAN UNIVERSITY

the regular sized canister were also made on a canister testing machine, the principle of operation being analogous to that of the tube machine, but with a larger portion of absorbent assembled in the canister exactly as when in use. To further check the efficiency of defense against new gases, the "man test" was devised, by which the actual time during which it was possible for a man to breathe through the canister before any traces of gas appeared was determined. The regular canister and mask were used and the concentration of gas was set up inside a chamber, the break point being deter-

more exposed portions of the line men who were almost certain to become casualties on exposure to it. Considerable work was also done in studying the manner in which certain gases act upon the skin. Just as in the case of soldiers wounded by high explosives, where the skill of the army surgeon is exhibited to a very high degree, so in the development of the entirely new technique of gas warfare was it necessary to invent means for protecting the soldiers against gas and for restoring them to health as rapidly and as completely as possible once they had been exposed.

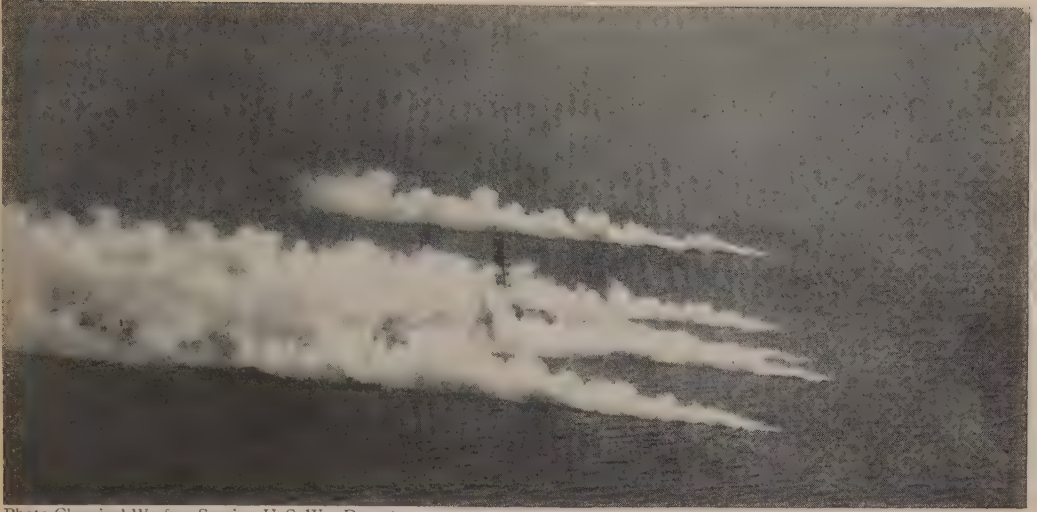


Photo Chemical Warfare Service, U. S. War Department

SMOKE SCREEN HIDING A BATTLESHIP

It is interesting to note briefly some of the accomplishments of the Chemical Warfare Service in the United States. At Edgewood Arsenal, erected in nine months at Edgewood, Maryland, where at the close of the war there were over 7000 chemical warfare men and 3000 civilians employed, an enormous amount of toxic material was manufactured. Over 22,000,000 pounds of toxics were produced and about 8,500,000 pounds actually shipped overseas in bulk. About 1,400,000 gas shells, grenades, etc. were filled, and nearly 700,000 shipped. At the end of the war the United States had a capacity for gas pro-

duction greater than England, France and Germany combined. On the defensive side, about 5,700,000 gas masks were manufactured and 4,139,000 shipped.

Admittedly war is a terrible thing, yet so long as humanity resorts to this method for settling disputes, so long must the various nations be prepared to wage war in all its branches. Preparedness is the best means of prevention. Undoubtedly chemical warfare has come to stay, yet because of a lack of definite information regarding this relatively new branch, we are continually told that it is the most inhumane and barbarous method of waging war.



Photo Chemical Warfare Service, U. S. War Department

WHITE PHOSPHORUS BOMB BURSTING AT THE BASE OF A 90-FOOT TOWER

Statistics all show the fallacy of such statements. In speaking against the use of gas in war, one of the high army officials has called attention to having seen in France numbers of small children brought in from districts back of the lines suffering from gas in their lungs, innocent little things who had nothing at all to do with the game of war. But we do not ask that the use of artillery be discontinued because a shell from a long-range gun, bursting through the walls of a Paris church on Good Friday, kills women and children on their knees in prayer. It is a terrible thing to contemplate that beneath hill No. 108 near Rheims were buried alive more than ten thousand men as a result of its thrice-repeated mining. Yet no one thinks of suggesting that we give up the use of explosives for mining.

The terrible results of the early German gas attacks were due only to the fact that the Allies had devised no protection whatsoever against it. Chemical warfare loses many of its terrors when the combatants are prepared both for defense and offense. The medical records of the United States Army indicate that out of every one hundred Americans gassed less than two per cent died, whereas from the same number of casualties due to other causes more than 25 per cent succumbed. The number of permanently injured from gas has also been shown to be very low and it should be emphasized that gas serves largely as a weapon for temporarily removing the enemy from combat or for reducing his fighting efficiency.

During the latter part of the war and since then more powerful toxic materials have been discovered against which the early methods of protection are relatively ineffective. Problems incidental to obtaining the raw material in sufficient quantities, to the manufacturing on a large scale, to using them on the field, and to devising methods of protection against them, require considerable time for research and solution. It is vitally necessary that a nation should be prepared to defend itself against new gases which may be discovered, and the study of defensive and offensive measures must go hand in hand. Though the production of a new toxic material for chemical warfare is difficult, much of the work can be conducted in an ordinary industrial laboratory, and any nation with a well-developed chemical industry could, therefore, make investigations secretly along this line regardless of agreements, and secure a tremendous advantage in time of war. Long as it takes to train the various arms of the service, it can be accomplished in an infinitely shorter time than is required to develop new types of toxic compounds, prepare them for actual use on the battlefield, satisfactorily protect against them and instil into an army the requisite knowledge of chemical warfare technique. The introduction of gas entirely revolutionized the tactics of field warfare. In order, therefore, to prevent gas casualties, the soldier must be thoroughly educated in the use of this new and powerful weapon, and brought to a very high degree of efficiency.



Photo Chemical Warfare Service, U. S. War Department

DIRECT HIT ON THE FIGHTING-TOP OF A BATTLESHIP WITH A WHITE PHOSPHORUS BOMB

HOW THREE-COLOR PLATES ARE PRINTED



MRS. COOLIDGE ROSES IN A TIFFANY VASE

The subject is photographed three times, through color filters. First through a violet filter to subtract all red and blue, isolating the values of yellow throughout. Secondly through a green filter, subtracting the yellow and blue to leave the red tones. Thirdly through an orange filter, eliminating the red and yellow and yielding the blue values. The resultant halftone plates, made in the usual manner on copper from the separate negatives, are then printed, superimposed, in exact register with effect shown.

THE MAKING OF WEALTH

How Industry and Trade Have Always
Been Checked by Misdirected Effort

THE POSSIBILITIES OF EXPANSION

THE essence of the production of material wealth is to form new combinations of the matter supplied by nature, and industry and commerce alike are concerned with a useful exercise of motion. On analysis we see that all manufacturing is the issue in the form of useful articles of work done by moving into new positions the materials which nature supplies. We cannot either create or destroy matter, but with increasing effectiveness we can create or destroy utilities. We do not create matter when we cut down a tall tree and turn its trunk into timber, but we do create a new utility — timber. We do not destroy matter if we burn the timber; the matter is indestructible, and all that we do is to reduce it to other forms — gases, smoke (unconsumed carbon) and mineral ash. The burning, however, has destroyed utility, although it has not destroyed matter.

It is not possible for man to waste matter, it is only possible for him to create or waste utilities by changing the form of matter.

But man is ever filled with a desire for new forms and kinds of goods. As his powers increase, and as his command of nature increases, he demands an ever increasing complexity of manufactured articles. His desires are without limit. He calls for houses of the most complicated description, for clothes and personal ornaments of constantly changing type and of great elaboration; he demands for the fuller enjoyment of his powers the constant use of an enormous range of utilities in the shape of prepared foods, furniture, utensils, books and papers, instru-

ments of sport, musical instruments, vehicles, etc. The ever-growing facilities for the conduct of agriculture therefore serve to set free an increasing proportion of working people to devote themselves to manufacturing. The call for agricultural work has decreased, and must, relatively, decrease. The call for the products of industry is ever growing.

Well-ordered movements produce wealth, but labor consists of movements not always well ordered. Labor, then, is a source of wealth; but it would be a mistake to suppose that all labor produces wealth, for much of it is not well ordered.

When we say that labor is not well ordered, we mean that it is wasted, that is, that it is not exerted in such a way as to contribute directly or indirectly toward increasing the stock of utilities which consumers are demanding. It requires as much labor to sink a deep well in a region in which, for geological reasons, there is no possibility of finding oil as to sink as deep a well into rich oil-bearing strata. But in one case the labor is wasted, and in the other it is productive. Men confined to their homes by illness, or in prison by a court sentence, sometimes while away the tedium of their lives by carving absurdly intricate and fanciful articles of wood. Even though they may have cost years of labor, such articles generally have no value, except perhaps in unusual cases as curiosities. We should see clearly that it is *not labor that gives value to goods*. It is the value of the goods produced which gives value to labor. Labor does not create value; the value of labor is nothing but the reflected value of what labor produces.

Moving to the place wanted as important as making the article

We have the further complication that what is a utility to an individual may not be a utility to the society of which the individual forms a part; and, as we have seen, when we have estimated the wealth of a country and expressed it in currency, we have an estimate of wealth which may not be in entire accord with well-being.

In this connection arises the very important considerations connected with productive and unproductive labor. We pointed out in an earlier chapter that a person may be a useful "producer" although he is not directly engaged in constructing material commodities. This necessarily follows from the consideration that it is just as important to move an article into the place where it is wanted as to make the article itself. The pair of shoes at the factory in Massachusetts is useless to the person in Virginia, where they do not make boots. The Virginian could not walk to Brockton or Lynn to obtain the shoes; and the labor exerted, therefore, in conveying them from Lynn to a store in Virginia is obviously just as "productive" as that employed in making the boots themselves. The railway men, the teamsters and eventually the storekeeper, are seen to be truly productive in their movements.

Yet it does not follow every conveyor or dealer is a wealth producer

But that by no means exhausts the treatment of this important point. It remains to add that while it is true that a conveyor of goods, or a storer of goods, or a dealer in goods may be a truly productive laborer, it does not necessarily follow that every such conveyor or dealer is a wealth producer. He may be producing something which has utility in relation to the circumstances in which he is employed, but it does not necessarily follow that those circumstances are justifiable or that they could not easily be dispensed with.

Take, for example, the case of two small manufacturing firms engaged in making the same product. If we consider the na-

ture of their operations, we see them renting two separate factories and two separate offices, and each employing a certain number of work-people. Thus established, they compete in the same markets for an amount of trade which is limited by the consuming power of the buyers in the market. They each keep, of course, separate accounts, and find it necessary to print separate stationery, and separate labels. They have also to employ separate clerical staffs, separate sets of traveling salesmen, and they issue separate advertisements. It will readily be perceived that each of the persons engaged by the two firms is producing utilities under the given circumstances; each of the clerks and travelers is necessary under the given circumstances.

How duplication of business may make part of the labor employed non-productive

The point remains, are the given circumstances necessary? And from the point of view of society, is each of the persons employed by the two firms producing social utilities? If we imagine the two firms to combine their operations, we see that they would not require separate offices or separate accounts, or separate traveling salesmen or separate advertisements, and that it would probably be as simple, or even simpler, to manage the two businesses as one than to manage the aggregate business as two. Given fresh circumstances — viz., amalgamation of the two economic units into one economic unit — and a certain considerable amount of the labor before employed by the two separate firms is seen to be economically useless, and productive not of social utilities but of social waste.

Wastes of this kind, however, — wastes that arise from the unnecessary duplication of manufacturing or distributing units — are probably less important in the aggregate than is sometimes supposed. That such wastes do persist in some fields is not, properly speaking, a fault inherent in the competitive system. The wastes are to be attributed, rather, to the fact that the competitive system is not perfectly and rigorously enforced. Take, for example, the

case of the two manufacturing competing firms just discussed. If there were real savings to be effected by their consolidation, it is perfectly clear that it would pay the proprietors of one firm to buy out the other, for, by reason of the savings which consolidation would introduce, the competing plant would be worth more to the buyers than to its original and separate owners. Or if the proprietors of the first plant lacked the capital necessary for such a transaction, some enterprising promoter would be fairly sure to see an opportunity for profit in the operation of buying both establishments, consolidating them, and selling the consolidated business, at a profit, to a new group of investors. Such transactions are, in fact, being carried out every day. If consolidation always meant economy, there would be no effective limit to consolidation. That means that competition would inevitably everywhere end in monopoly. But, as we all know, in most fields of economic life competition maintains its health and vigor. This proves that the supposed benefits of consolidation are often illusory.

The number of people who work hard but add nothing to the country's wealth

Take the case of the corner drug store. It happens that on some kinds of the large variety of proprietary goods carried by drug stores, the margin between the wholesale cost and the retail selling price is fairly large. That is, what the accountant calls the "profit on the turnover" is relatively high as compared with the profit to be had in some other fields of retail trade. Does this mean that the druggist is always a man who makes abnormal profits? By no means. Just so far as the average profit per unit of sales is high, just so far will there tend to be a multiplication of drug stores. A drug store can survive on a relatively small gross volume of sales because the average profit per sale is fairly high. Retail stores in other fields need a larger volume of sales. But is not this apparent duplication of distributing agencies, such as we find in the case of retail drug stores, an economic waste? Would society not be better

off if the business of retailing drugs were in the hands of a relatively small number of "cut-rate" drug stores? From some points of view, yes; from other points of view, no. The wastes are obvious, but there is a real social advantage, it is proper to say a real social utility, in having retail distributing units conveniently accessible. Loss in the duplication of clerks, of rentals, etc., is offset, to some extent at least, by the time and effort saved consumers.

The problem, therefore, is complicated. It is clear, however, that the mere fact that a man is at work, and working strenuously in that work, does not necessarily mean that he is a productive worker. Through no fault of his own, but through the imperfect organization of trade, he may be doing work no more valuable to society than if he were digging a hole, and filling it up again. There can be no doubt that in a community of over 100,000,000 people, such as the United States, the number of persons who, although they work arduously, are not really engaged in adding to the wealth of the country, is very large.

The erroneous view of those who deny a carpenter "makes" a table

It is never enough to say that people are employed or unemployed; it is all-important that we should know *how* the employed are employed. We sometimes find economists, in their anxiety to abridge the distinction between productive and unproductive labor, denying that man can "create" anything, and asserting that it is a careless use of the language to speak of a carpenter, for example, as "making" a table. As a matter of fact, a carpenter who asserts that he has made a table is much nearer the truth than the economist who denies the fact. It is perfectly true that a carpenter does not create the matter out of which the table is formed, and that the table is an expression of his skill in utilizing natural materials and his wisdom in so fashioning the materials that they take form as the entity we call a table. A table, however, is not wood, but a created utility embodying the skill, the experience and the judgment of men; and as such it is a real creation.

The dependence of true employment on whether a man is creating utility

That cannot be said of the products of the unnecessary clerk making a superfluous invoice, or of ten shopkeepers doing a distributive trade which could be conveniently carried on by one-fifth of their number.

It is false to conclude that all those whose labors satisfy existing wants are to be truly regarded as taking part in production, or that they can be called "productive laborers". It cannot be too strongly insisted upon that honest and arduous work may be, and undoubtedly is, often exerted in forms which are without advantage to the wealth of a nation, and that it may but serve to attenuate the earnings of those who produce usefully.

It is only too true, unhappily, that in the United States, or in any of the great modern civilizations, a limited number of economically employed workers carry on their backs a host of workers whose work is poured out in waste, and who, themselves not really producers, consume the products made by others.

The fault, however, does not reside in the organization of production so much as in the organization of consumption. In a literal sense, we must admit, commodities for which people are willing to pay, commodities which they demand, are by that very test commodities which satisfy human wants. In other words they are commodities which have utility. The economist can distinguish between higher and lower utilities only by invoking some non-economic criterion, — in general, some moral ground of distinguishing between utilities which are useful and utilities which are not useful and which may be even harmful. In most cases there is little doubt in the mind of the man of common sense as to the fact that some things are more useful than other things. There are marginal cases; there may be some disagreement about the utility of certain forms of recreation, of the drama, or even of different kinds of foods and beverages. But these are matters to be decided, not by the economist, but by the moralist, or, in some instances, by the physiologist.

Mistake of supposing that the army and navy are not productively employed

What we have said is recognized by many people to be true in respect to the army and navy. The United States had a population in 1920 of over 100,000,000, of whom about 25,000,000 were males of military age. Of these 25,000,000 males we employed about 100,000 for the navy and about 150,000 for the army; or, say, 250,000 men in all. We often hear it said that these 250,000 men are idlers who consume without producing, and in one sense this is incontrovertible. They are picked men, our soldiers and sailors, and we train them in physical exercises to make them strong and efficient. How much they might do, we often hear it said, if they were trained also in productive work, and set to produce material good for consumption! If we take their output as worth no less than \$800 a man per annum, *we should have an addition of \$200,000,000 to the goods produced in the country in a year.* It is useless to repine on that account, because we know that these men are needed, in view of the circumstances of the imperfect civilization and settlement of the world; and if we regard them as guarding the nation as a whole, they may claim to be as useful as any other members of the community. Indeed, our soldiers and sailors may claim to be much more useful than many other groups of men and women of similar proportions that could be named as wasting their time and consuming goods which they do not produce.

The number of economic hangers-on in our great civilization far outnumbers our soldiers and sailors. They consume goods which someone has to make, while they themselves add nothing economically useful to the national undertaking.

The greater call for labor that comes from the most widely distributed wealth

It will be realized that a call for commodities is, in effect, a call for labor. As we spend our money, so we direct people to work for us. If we call for clothes, we employ men and women in the textile and clothing trades, and indirectly we call

planters to grow cotton and herders to raise sheep. If we elect to be less fine in our persons in order to secure better houses, then we command men to come into the building trades, and we command the various trades of brick and tile making, the making of glass, the making of cement, of lumber, etc., to supply materials to the builders of our homes. If we become a pleasure-loving people, and spend a considerable part of our incomes upon amusements, then we inevitably turn men and women into actors and actresses, professional singers and dancers, builders and furnishers of places of amusement, professional baseball players, jockeys and so forth. Clearly realizing this, we perceive that the total production of the country, the nature of the production of the country, and therefore the character of its trade, must vary with the manner of the distribution of wealth.

The man of small and moderate means — we speak of the average, healthy, decent man — spends by far the greater part of his income upon the necessities of life. Indeed, he is compelled to do so if he is to keep his home together and his family in modest comfort. The first requisite is a home, and so much has to go in rent; the second is food; the third, fuel and light; the fourth, clothes. As incomes rise in the scale, the proportion of the expenditure of income upon these things varies, and other things are called for in increasing proportion. We may note that, however big a man's income gets, he does not increase the call for certain things very materially. He does not grow additional feet with his additional income; and even though he has ever so ample a supply of footgear, there is not the same proportion of his income spent upon boots as in the case of the man with twenty dollars a week. The existence of a limited number of very large incomes taking a great share of the national dividend, and of a large number of very small incomes, must mean that the industries providing necessities are not nearly as large as they would be if there were a more equal division. The rich man, by his expenditure, encourages the industries providing luxuries more than those providing necessities.

Engel's laws; how the average family budget is made up in different countries

In 1857, Dr. Ernst Engel, a distinguished head of the Prussian Statistical Bureau, published statistics showing the way in which the expenditures of working men's families in Saxony were distributed. From these tables and others like them, he deduced certain conclusions to which the name of "Engel's laws" is sometimes given. His first conclusion was that families with larger incomes spend a smaller proportion of their incomes for subsistence than do families with smaller incomes. This conclusion, the reader will say, might be derived from common observation, and scarcely needs to be bolstered up by elaborate statistics. But Engel's second conclusion is not so easily derived from general observation. It is that the per cent of a family's income spent for clothes is approximately the same, whatever the income. His third conclusion is even more striking, namely, that the percent of the income spent for housing, or rent, and for fuel and light is almost invariably the same, whatever the income. The reader will understand that these statements are intended to apply to average families, and that individual cases may deviate considerably from these "laws". Engel's final conclusion is nothing but a simple corollary of the others, namely, that families with larger incomes spend not only absolutely but relatively more for sundries and luxuries of various sorts.

Since Engel made these pioneer investigations many similar studies of family budgets have been undertaken. The findings, in general, agree with those of Engel. Take, for example, some figures relating to the standard of living in New York City.

EXPENDITURES OF 12,000 FAMILIES IN 92 CITIES

(From U. S. Bureau of Labor Statistics)

FAMILY INCOME	PER CENT OF INCOME EXPENDED FOR:			
	Food	Clothing	Rent	Sundries
\$ 900—\$1200	42.4	14.5	13.9	29.2
\$1200—\$1500	39.6	15.9	13.8	30.7
\$1500—\$1800	37.2	16.7	13.5	32.6
\$1800—\$2100	35.7	17.5	13.2	33.6

The per cent of income spent for food decreases as we pass from lower to higher income classes, — except that the very poorest, being confronted by what may be called an irreducible minimum of necessary expenditures for other purposes, find themselves compelled to get along with the cheapest kind of food, and therefore spend relatively less for it than do persons in slightly higher income classes. Engel's conclusion that the per cent of family income spent for housing and rent is constant has been found by most later investigators to be an extraordinarily accurate generalization. It holds true not only for working men's families, but also for persons in much higher income classes. But because housing of any sort in an American city has, under practical conditions, a minimum cost below which it is impossible to go, the very poorest classes have to spend a somewhat larger per cent of their incomes for rent than do those who are better off.

On the manner of distribution of wealth depends the ordering of production

It is clear, therefore, that the demand for goods and the consequent ordering of production will depend in very large measure upon the way in which wealth is distributed. We do not propose in this chapter to bring under review again the facts relating to the present distribution of wealth, for these have already been discussed in Chapter 21. We found, it will be remembered, that, while inequalities in the distribution of income are great enough to be matters of serious national concern, they are far from being as irremediably bad as the exaggerations of pessimists would have us believe. In general, the lower the average family income and the more equality there is in the distribution of incomes among families, the greater will be the demand for the necessities as contrasted with the luxuries of life, and the larger, therefore, will be the proportion of the nation's labor force which is utilized in the production of unquestionably useful goods.

Observe, however, that it is necessary not only that the average family income should be relatively small, but also that there should be no large degree of inequality in

the distribution of wealth. The first condition is necessary because, even if the distribution of wealth is fairly uniform, relatively large incomes would give a *surplus* to be spent for things in addition to the obviously necessary utilities of life. The further condition, that incomes must be evenly distributed, is necessary because it is possible to have a relatively low average family income together with a high degree of inequality in the distribution of wealth; if the mass of the people were in poverty and if a relatively small number received very large incomes, the "average" income might easily be low, and yet a large proportion of the nation's labor might be utilized in the production of luxuries of more or less doubtful social utility.

An even distribution of wealth would result in monotonous uniformity of life

One should not too hastily conclude, however, that it is certain that the nation's labor would be best utilized if there was an approach to something like a dead level in the distribution of wealth, and if no family had at its disposal any large surplus income above the amount necessary to provide for its fundamental and immediate wants. Under such circumstances it is hard to see how there could be anything beyond a dull, drab, monotonous uniformity in the conditions of life. The mere multiplication and perpetuation of a large population living in a routine fashion, providing itself only with the necessities of a humdrum existence, is not an ideal to stir the imagination of one who is honestly interested in the progress of his country and of humanity.

A surplus somewhere in the economic system necessary for the higher interests

Somewhere in the economic system, there must be a *surplus* which can be used to provide for the higher interests and values of the community, for the advancement of pure science and the increase of human knowledge, for the sustenance of art and music and letters, for the achievement of public works of lasting beauty. Those periods in the world's history which have bequeathed rich cultural legacies to

later generations have been periods in which a disposable surplus, over and above the amount necessary to provide for fundamental human wants, existed. Athens built the Parthenon out of funds confiscated from, or, shall we say, *embezzled* from, other Greek cities. In the Italian Renaissance, literature and the arts developed under the patronage of men who had amassed their fortunes in ways which, judged by modern standards, were often no better than robbery. Even in our own day, no small proportion of the wealth which has been concentrated in the hands of the extremely rich has gone ultimately to libraries, to art museums, to the promoting of education and to the advancement of science.

Just what is a productive laborer in the ultimate analysis?

Facts like these must arouse reflection. Is not the artist or the poet, from the point of view of the long-time interests of the human race, quite as productive as the purveyor of food or clothing? And when we think of the way in which modern industry is built upon and supported by modern science, must we not conclude that the scientist himself may be a very important producer of wealth? We should remember, too, that the largest advancements in science have often been made by men who were working only for love of the work, who had in mind no important practical application of their results to industrial problems. The man with the practical problem in mind is likely to have his vision somewhat narrowed. The largest view is possible only to the man who works with his eyes upon no near goal, but who has them lifted to the distant horizons which limit human knowledge.

Raising the level of popular taste by education to appreciate beautiful things

Must we conclude, therefore, that large and permanent inequalities in the distribution of wealth are necessary in order to dispose of the surplus upon which progress of human civilization seems largely to depend?

No, not at all, for there are other and better ways of achieving the same end. One is through education of a sort that will gradually raise the level of popular taste so that things which are beautiful as well as immediately useful will be numbered among the real necessities of life. To direct production into the best channels it is necessary only to change the tastes, the standards, and desires of the consumers who command the productive army. A second way of achieving the same end is through the increase of public expenditures for higher education, for science, for art, for music and for wholesome recreation.

The advantages of public expenditure that lead to production of inclusive utilities

Public expenditures of this kind have the great advantage that they lead to the production of utilities which are *in-*, rather than exclusive. The picture in the rich man's private gallery is a utility — to him and to his friends. The same picture in a public museum is a larger utility. Public expenditures are becoming more and more wisely adapted to achieve the important ends we have discussed. New and better standards are being maintained for public buildings, for public memorials of various sorts, and new emphasis is given to public expenditures that bring utilities of the finer sort within the reach of all the people.

Economic and social progress require surplus of production over bare necessities

A surplus of production over and above the routine necessities of life is, as we have seen, prerequisite to economic and social progress. But the surplus need not be procured by robbery or extortion, nor should it make necessary a perpetuation of extreme inequalities in the distribution of wealth. A surplus, in other words, may be democratized. It may be concentrated in part in public revenues and expenditures, or, better yet, it may be made up of the small individual surpluses which separate individual consumers may be able to amass and to expend for things which, even if not immediately and practically "useful", may nevertheless enrich and ennoble human life.

**Not all luxurious, but all extravagant,
expenditure to be condemned**

Not all luxurious expenditures are to be condemned as extravagant. Luxury, as has been said, is a vague something which society has always viewed with mingled tolerance and condemnation. Just what things are luxuries and what things are not, depends upon conditions of time and place. With the growth and diffusion of wealth, there has been a continual transfer of articles from the list of luxuries to the list of comforts and necessities. Careful analysis will reveal to the reader how much of his own consumption is, strictly speaking, unnecessary. Every year increases the list of what are appropriately called "conventional necessities". A very few dollars a year would suffice for satisfying the absolutely necessary minimum of physical wants. Everything above that low minimum must be classed as "comforts" and "luxuries".

Extravagant expenditures of whatever sort, however, have to be condemned. They are sometimes condoned on the grounds that they give employment to labor. This is just one form of the "make-work" fallacy prevalent in much popular economic reasoning. There seems to be a general impression that the welfare and prosperity of the country can be increased merely by increasing the amount of work to be done — as though we were interested in work rather than its fruits. This make-work fallacy is found in some (not all) of the arguments of trade-unionists, in discussions of a protective tariff, in various quack remedies for unemployment and other economic ills. One would gather from some of these arguments that social policies should be so framed as to make the production of wealth just as laborious and just as unproductive as possible.

Bastiat, a brilliant French economist, satirized these notions in his story of the glass-fitter. The glass-fitter argued that the more window panes were broken, the more employment he and his brethren would have, and the greater would be their demand for the labor and products of others. From this reasoning, it is an easy

step to the conclusion that the nation can be made prosperous if only enough windows are broken so as to give employment to the glass-fitters, who, in turn, would give employment to others! The absurdity of the notion that national economic policies should be framed so as to "make work" ought to be obvious.

**Society's costly amusements when poor
are having "a hard winter" immoral**

Some twenty years or more ago, an elaborate fancy dress ball was given in New York City in the midst of a winter in which an unusually large number of people were in poverty. The more sensational newspapers entered into a controversy over the morality or immorality of the extravagant expenditures connected with the ball. They estimated that the total cost, including costumes, ran into the hundreds of thousands, and possibly into the millions, of dollars. And yet many of these newspapers came to the conclusion that these extravagant expenditures were justifiable on the ground that they gave employment to workers in textile mills, to dressmakers, to milliners, to caterers, and the like. Money, it was urged, was in this manner taken out of the hands of the "idle rich" who did not need it, and distributed to persons who could use it to better advantage, and, through the expenditures of this latter class, it gave employment to many others. Now this type of economic reasoning, though frequently encountered, is utterly fallacious. It is perfectly clear that neither the family which gave the ball nor the guests that attended it, were in the habit of keeping their money locked up in strong boxes like misers. Just as far as they expended money on account of the ball, they *diverted* their expenditures from other objects. Dressmakers, milliners and the rest were given employment at the expense of others who would have been given employment if expenditures had been for other objects. But, the reader may say, even though the money was not taken out of hiding, it may have been taken out of savings, or out of investments, and its expenditure, even for a relatively wasteful purpose in

the midst of a season of distress, must have done some good. No, for we must not forget that saving and investment, under modern conditions, are merely certain forms of expenditures. Neither the savings bank, nor the insurance company, nor any other custodian of savings holds any large amount of idle money. The funds contributed by different savers are concentrated and set to work in public works, in industry and in agriculture. If, in order to make an extravagant expenditure, a man has to sell securities or other investments, he adds just that much to the supply of investments on the market. Someone must buy them and buy just that much less of something else.

In the last analysis we cannot help concluding that in modern economic life there is no choice between spending and not spending; the choice is merely between different objects of expenditures. Wasteful and extravagant expenditure is therefore never justifiable. It does not and cannot increase the aggregate amount of employment; it weakens the moral fiber

of the spender and of those who foolishly try to emulate him, and this harm is not offset by any positive contribution to the nation's wealth. And in addition, we must take account of the further loss of the objects of real utility which might have been called into existence if the spender had so willed.

The largest problems of the present day are those of consumption, rather than of production. What matters it how large a fund of wealth be produced annually, if that wealth is not of the kind that will really benefit the community? Labor and the productive energies of nature can be used for high or for low purposes, just as we, the consumers of wealth, the ultimate directors and governors of the productive process, decide. Large public expenditures on education are to be justified not merely because education, as statistics show, makes for productive efficiency, but also, and chiefly, because education of the right sort ought to make for increasingly higher and better standards in the expending of money and consuming of wealth.



"HIGHBRIDGE", THE VIADUCT FOR CARRYING THE CROTON WATER ACROSS THE HARLEM RIVER INTO THE ISLAND OF NEW YORK

A GREAT AMERICAN ROAD WINDING ALONG A MAJESTIC RIVER



© Cross & Dimmitt

Panoramic view from Crown Point, Columbia River Highway (the two views are continuous).

© Gifford & Prentiss

Crown Point, saluting the flag.

ROADS AND ROAD-MAKING

The Avenues of Trade and Travel on Foot
and Wheel in Many Times and Lands

THE DUSTLESS ROADS OF THE FUTURE

NO settled country can reach a high state of prosperity without numerous and good roads. That is a sweeping proposition, but it can be advanced with confidence, though other means of internal communication have developed rapidly during the last century, and may seem to challenge the importance of the common highway. In some degree the railroad has admittedly superseded the road; and in a few countries the waterway may almost be said to *be* the true road, though these latter canal-scored plains, quite manifestly, are exceptions. The rule is that while the railroad makes a few roads comparatively solitary, it makes innumerable other roads additionally necessary; and so, more than ever, the highroad is the avenue to social and economic prosperity and an accelerated civilization.

At once we grant that there are stretches on some of the world's great and renowned roads which fill the observer with a sense of sadness, so complete has been the triumph of the competing railroad. The main traffic of the grandest of all European mountain roads, that over the Simplon Pass, is now carried burrowing through the warm heart of the mountain. The St. Gothard is only a little less lonely because its track is more open and valley-like. Even the Brenner, the great "German Road" of the Romans from southern to northern Tyrol, and at wider distances from Italy into Germany, is kept in good condition chiefly for strictly local uses, or for the touring automobilist. And who now goes over the topmost section of the Arlberg road, from the little Vorarlberg state into Tyrol, though many be the travelers through the tunneled crest?

In wider and less occupied lands the railway has made the overland route of pre-railroad travel a memory. It has obliterated completely the prairie trail across our continent; but then that never was a true road, but only a preparation for one. The traffic on the greatest road in the world, the Grand Trunk of India, a road that comes within reach of a hundred million people, has been somewhat thinned down by the competing rail; but the very success of the through railways has made the construction of subsidiary roads imperative, and has opened up country that before was barely accessible. The mileage of good roads increases enormously with the coming of the railroad, which is not the competitor so much as the coadjutor and friend of the common road, and the advance agent of a civilization that the bettered road will establish.

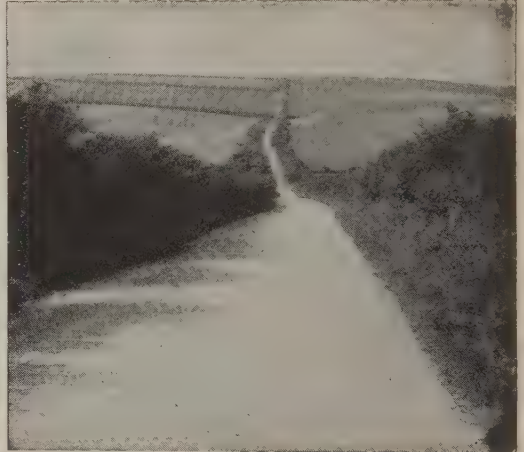
Everyone knows that the beautiful simplicity of isolated communities, even when they live in the midst of favorable economic and scenic surroundings, has many drawbacks. Whether they be tested by health, cleanliness, morale, or social amenities, the people whose lands have been opened to intercourse with the world have improved; and the first agency leading toward that improvement is the valley road that makes travel easy.

Though the life of isolation may produce an occasional strong character, its general effect on social development has been detrimental. Stagnation, narrowness, superstition and hampering tradition are often the fruits of such a life. A release to broader and higher ideals is secured when the highroad and railroad penetrate to the isolated community.

The historical division of roads into the few that are very old and the many that are quite modern — a product of the age of invention through which we are passing — is indeed striking, for it illustrates the extraordinary length of the period of industrial and mechanical stagnation between ancient and modern times. The Romans did many things as well or better than the European nations could do the same things until beyond the days of the English Stuarts. Gunpowder was almost the only gain for fifteen hundred years. When Hannibal was compelled to make a road for his army across the Alps into Italy, he could only use the methods invented by the ancient Egyptians. Small rocks were cleared away by hand tools and

Macadam was born in 1756, and Thomas Telford in 1757, and with these contemporaries a new era in road construction may be said to have begun. Since their day, however, road-making has transformed the world, and made comparisons with other times absurd. The countries that have not made roads are not in the modern age at all, as we see at once if we compare the roads, for instance, of France and Spain.

The history of the highway is a story in four chapters. First, is the story of the man who walks; next, of the man who rides a horse; then of the man who uses a wheeled vehicle drawn by animals; and, lastly, is the story of the man who rides on or in other forms of wheeled conveyances. We think now almost entirely



ROMAN ROADS IN USE TODAY IN ENGLAND

wedges. In the case of very large stones, the fire-setting system was adopted. The rock was heated by lighting a fire on it; and when it had grown very hot it was suddenly chilled with water, and the rapid contraction often caused it to split. It was slow work; and when the road-makers found themselves face to face with a mass of granite too large to be broken by hand tools or fire and water, they had to twist their path round it. Now all is changed; and the making of the modern road is an incident in the great drama of the mastery of space and time that has been proceeding so sensationally. It is indeed true that modern road-making is a matter of the last 160 years. John

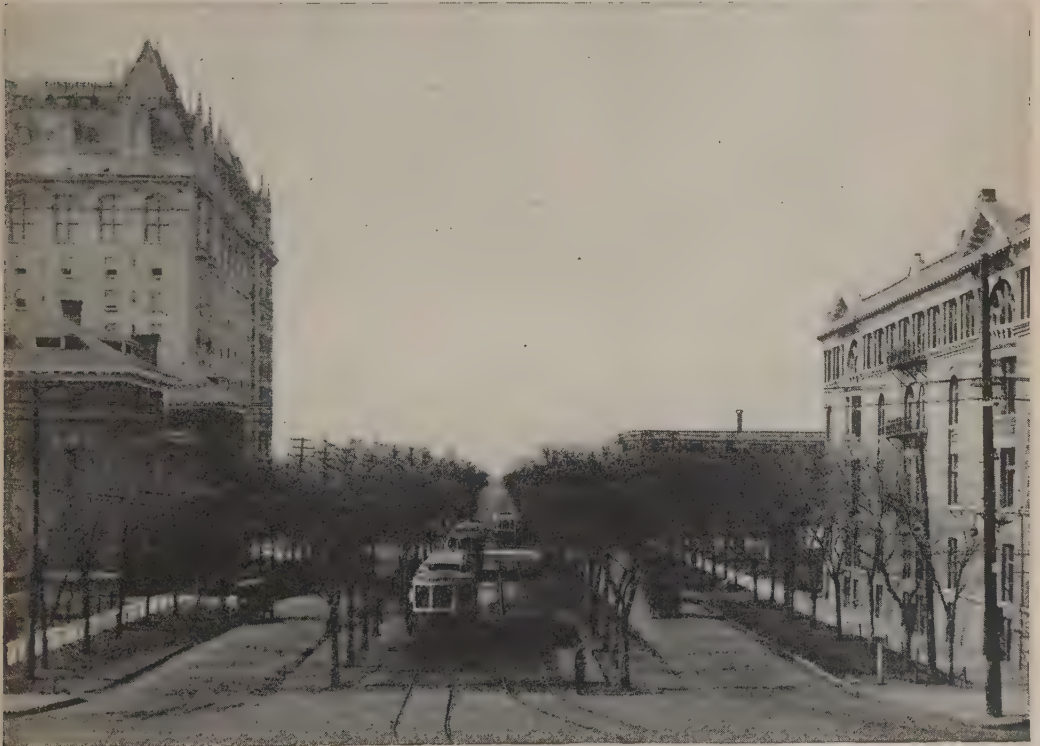
of these two last modes of movement, but the others are behind them.

The first roads were tracks, foot-paths, trails; and they were designed chiefly to keep the traveler out of wet places. One may see the process still in many a winding country road. Can it be that the sentiment that surrounds a foot-path, anywhere, everywhere, among the rocks, across the dry shoulder of the hill, and across the gap into the next valley — can it be that that sentiment is an unconscious rever-sion to the primitive days when the single-file trail was the only road? Half the charm of the country, whether we wander through meadow, or wind our way through the woods, or climb the hills, comes from

ROADS OF THE OLD LANDS AND THE NEW



A STONE-PAVED STREET IN POMPEII, SHOWING A STEPPING-STONE CROSSING



BROADWAY, WINNIPEG, CANADA — AN IDEAL MODERN CITY AVENUE

the faint romance of the foot-road. The instinct of the African following his forest track from the coast to the interior, or the Indian of the New World traversing the wood that is trackless to the stranger, or the mountain guide who walks with eyes that trace a way ten miles off, lives in a dim way in almost every man — a scarcely heard racial echo from the primeval world.

Nor is the bridle-path, the next stage in the evolution of the road, deprived of sentiment. One feels it when one stumbles upon the deserted packhorse trail across the Rockies, and pictures instinc-

Rather curiously, some of the most prosperous lands on earth are but slowly beginning to understand the true place of the road in national economy. The conspicuous examples are the United States and Canada. Here, speaking broadly, true road-making is only just beginning; and, to a considerable extent, this is due to the automobile. As the bicyclist found the meaning of the term "gradient" through the use of his muscles in riding the wheel, so the automobilist came to realize practically what a road should be when he began to scour the



A SURVIVAL FROM ROADLESS TIMES — MULES CARRYING STONES UP A ROUGH TRACK AT SORRENTO

tively the cavalcades of the vanished years; nay, one even feels it when in the Pyrenees or the Alps short-cuts on the old mule-paths are taken while the tame road with the stage-coach winds smoothly and slowly below us. The energetic and educated little countries — such as Switzerland and Norway — have fully realized, as backward countries like Spain and Turkey have not, that the road for wheeled traffic is indispensable; and the mule-path is becoming a romantic inconvenience, that only satisfies the parts of the world still slumbering under semi-civilizations.

world above the adhesive wheels of a costly car. These prosperous, flat, agricultural, new sections of our country got on very well without any roads worth mentioning, except in the great cities and long-settled districts, until they wanted to sail along at forty miles an hour in an automobile. Nothing strikes a visitor from the Old World to the New so quickly as the makeshift character of many of the roads, even in considerable towns. Only the main streets are streets at all, judged by their paving; and the native-born are blandly unaware that anything is wrong.

THE IMPROVEMENT IN AMERICAN ROADS



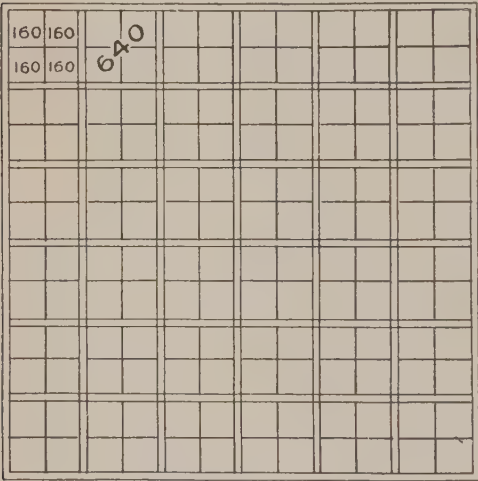
A MASSACHUSETTS ROAD BEFORE THE DAYS OF MOTORING



THE SAME ROAD AS IT HAS BEEN IMPROVED TODAY

Partly through the use of the automobile, and partly through the general advance of science, the American people are beginning to realize the need for good roads, and the several states are undertaking their construction on a large scale.

The explanation is simple. Until a town or city is sufficiently organized to be able to afford a debt, it does not admit of the need of a road. It suffices to leave a wide strip of the plentiful land, in its natural state, where vehicles may pass. When part of this common passage across the ordinary soil becomes rutted and water-logged, vehicles pass somewhere else on the broad track, until the whole of the site of the future street has assumed the appearance of a plowed field across which heavy wagons have been drawn. Mean-time, the inhabitants walk on plank "side-walks". Presently the city develops till it can borrow money for public improvements, and then road-making begins.



CANADIAN ROADS A MILE APART, AS SURVEYED ON A PRAIRIE TOWNSHIP

The fact is that road-making must always come at a late period in economic organization, and be a coöperative effort.

The problem: When should roads be made? begins with their first need in virgin country and continues after the latest act in town planning is put into force. The whole prairie area of Canada, for example, is surveyed for roads; that is, the country is laid out in townships of six miles by six, with spaces allowed for broad roads, at right angles, every mile, and roads-to-be running north and south and east and west. The accompanying diagram of a township shows the arrangement by which Canada leaves room for its roads of the future—a broad

road surrounding each square mile, and a narrower road intersecting each square mile (640 acres), and dividing it into quarter sections of 160 acres—that size being the unit of Canadian farm occupation. Thus, every farm has a possible road on each side of it—open prairie staked out and left for a road.

In English towns where land is the chief expense, the serious problem arises, as estates are laid out for building, shall the roads be first prepared as a prime necessity, or shall the houses be first built, and the roads be allowed to come into being, as avenues with a sound surface, with such slowness or swiftness as the complaints of the inhabitants, or the energy of the local authority in putting pressure on the owners of the adjoining houses and lands, may determine? In Germany the preparatory system prevails, and if houses are to be built satisfactory roads are made beforehand. In England, chance, modified by pressure and agitation, is characteristically preferred, on the ground that capital cannot be spent reasonably on roads until profits are being made on the houses adjoining such roads. In fact, England follows the plan of waiting for the well-made road till press of population makes it inevitable, and, from the point of view of capital, much easier to construct. The more thorough German thinks that, as there must be a road, it is better to have it made beforehand, and so secure sanitary advantages and convenience of transit from the moment the new houses are in use.

The Roman, the first great road-builder, worked with a much clearer idea of the true value of the road. He saw far ahead and knew the folly of holding off from spending as long as possible. He drove his roads to the furthest limits of his empire, and made them to last all time. The result is that some of them have been in use over two thousand years. The Appian Way, known to all visitors to Rome, was begun by Appius Claudius in the year 312 B.C., and so has been serving mankind for more than twenty-two centuries. We know of nothing else made by man that has served him so long.

THE HIGHEST AUTO ROAD IN THE WORLD

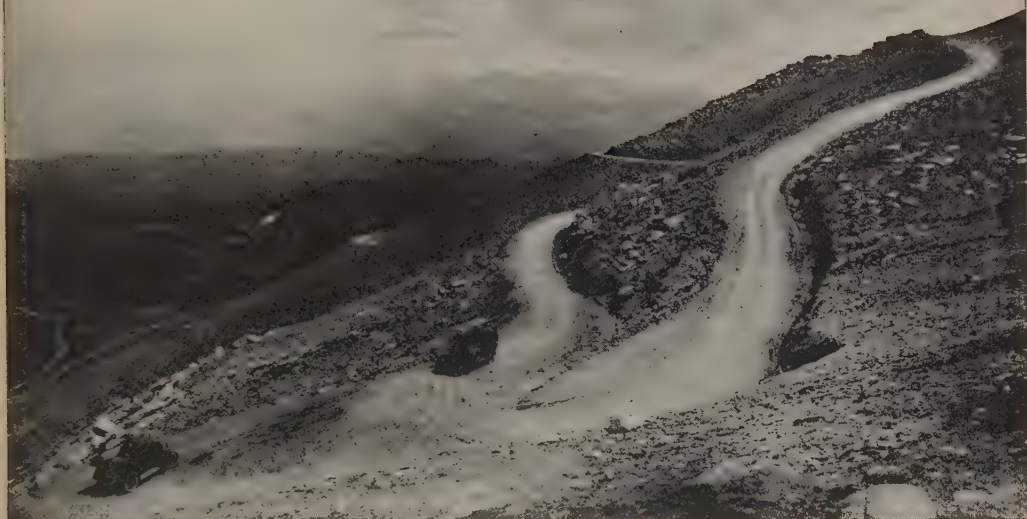


Photo Publishers' Photo Service

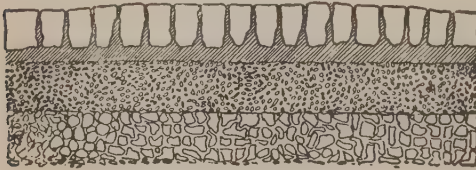
THE SERPENTINE TRAIL, PIKES PEAK AUTO HIGHWAY



Photo Pikes Peak News Bureau

AIRPLANE VIEW OF UPPER SECTION (14,108 FEET ABOVE SEA LEVEL) OF PIKES PEAK AUTO HIGHWAY

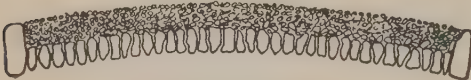
A view of the Appian Way today does not, however, tell us what it was like in the far-off past. Only in two respects does it necessarily preserve its ancient features. Those two are its straightness and narrowness, as indicated by the ruins of the tombs that flank it. Roman roads, though built with such foresight and thoroughness, were always narrow, and only two conveyances could pass at once. The paved part, even on the Appian Way, was but fifteen feet wide, and there was a drainage trench on each side that would make careless driving dangerous. The



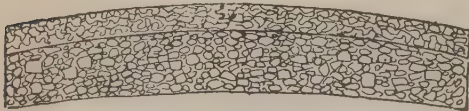
Roman road



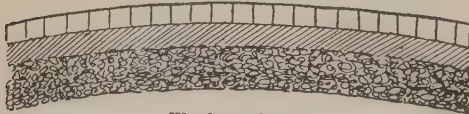
Seventeenth century road



Eighteenth century road



Modern Macadam road



Wood-paved road

DECLINE AND REVIVAL IN ROAD-MAKING

dominant feature of the road, unfamiliar to us now, was the paving—a closely cemented level flooring of flagstones, making an absolutely stone road, that rested on a foundation of prepared stone or concrete, nearly a yard thick. In short, the surface of Roman roads was like the hardest of city pavements of the present day, as smooth and as regular. It was a causeway for vehicles, with narrow walks on either side for foot passengers.

In making it, a trench was cut on each hand, the soft earth removed, and the under layers bedded hard by ramming;

then several courses of flat stones were laid in mortar; above this a course of rubble masonry or concrete was added; next, a final layer of concrete, and on the top blocks of stone were carefully fitted and joined. That was the ideal Roman road—really a great smooth causeway of masonry in the neighborhood of the cities, and exceedingly substantial in the country wilds, as may be judged from such remnants as are left after fifteen to seventeen hundred years of waste.

But these good roads—probably never commodious enough for the wants of a considerable population exchanging its goods at great distances—had become a faint tradition in Europe by the middle of the eighteenth century, and every reference one can find to roads at all at that time is a bitter complaint, even in the days when wheeled traffic was a rarity. A journey for many hundreds of years was a genuine adventure; and prayers were needed for all who traveled by land quite as urgently as for those who traveled by sea. So much was this the case that road-making and bridge-building ranked high as religious duties. Indeed, in the twelfth century a religious order, the Pontife Brothers, was founded on the Continent for the purpose of bridge-building. So bad were the English roads in the fourteenth century that the meeting of one of the parliaments of Edward III was postponed specially to await the coming of the members delayed owing to this cause.

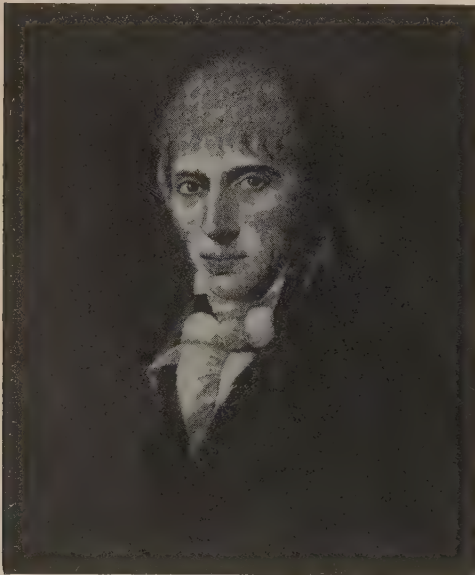
Out of this state of chaos England began slowly and experimentally to bungle its way, in the middle of the eighteenth century, by the formation of turnpike trusts. The trusts were established by law to make district roads, which they had power to bar with gates and so levy tolls; and besides these roads the separate parishes could make their own roads, and impose taxes on the inhabitants. A worse system could not well be imagined than that of turnpike trusts, which placed the whole road traffic of the country at the mercy of innumerable little, incompetent bodies; but by sheer pressure of circumstances and dint of complaints the main roads were gradually improved.

THE STELVIO PASS--THE ONLY MAIN ROAD IN EUROPE REACHING A HEIGHT OF 9000 FEET



THE AUSTRIAN SLOPE OF THE STELVIO BEGINS ABOUT 16 MILES FROM THE SUMMIT, AND THE UPPER SEVEN MILES ARE HERE SHOWN, AS SEEN FROM THE FOOTHILLS OF THE ICECLAD ORTLER SPITZ

The originators of the modern road-making systems were two Scotchmen — John Loudon Macadam (1756–1836), and Thomas Telford (1757–1834). Though there have been improvements on their plans, and modern conditions of traffic need fresh modifications of construction and upkeep, these men were the practical pioneers of sound roads. Some credit is also due Richard Lovell Edgeworth (1744–1817), the father of the novelist Maria, who, previous to Macadam's work, published an essay on the subject. He retains his prominence in this connection merely as a theorist, however, not having attained practical success.

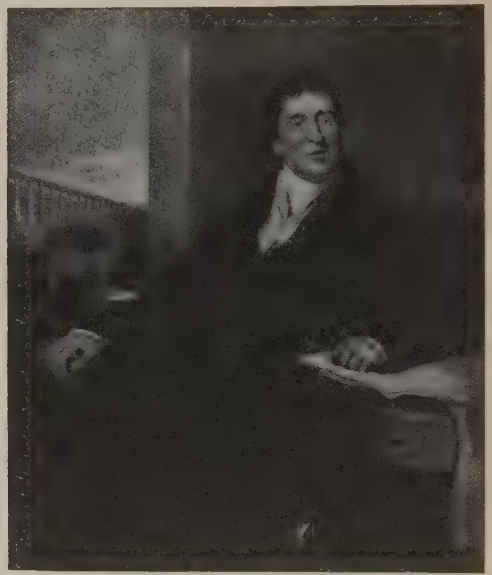


JOHN LOUDON MACADAM

Before Macadam revolutionized the practice of road construction, there were long periods of distorted ingenuity in spoiling good ideas. Admittedly, for example, a flat road is not a good road. Some slope for drainage is advisable both ways from the crown of the road. The common mistake of the road commissioner who only knows a little is to make the crown of the road too high; and this mistake was generally exaggerated in the days before Macadam, with the result that vehicles all sought, and kept, the crown of the road, which in consequence was quickly worn into ruts that became water traps.

Macadam insisted that it was unnecessary to have the elaborate stone foundations which the Romans had used, and that a good, smooth, hard surface could be maintained by spreading, ten or twelve inches deep, stones that had been broken into angular forms of such a size as to pass through a $2\frac{1}{2}$ -inch ring. The angles, he held, would fit and bind together. The weakness of his system was that it necessitated a very uncomfortable period when the broken stone was first placed on the road.

Telford began the construction of roads in the year 1803. His variation from Macadam was that he laid a foundation of large stones, with sufficient spaces



THOMAS TELFORD

between to allow of drainage under the road. Above this rough and strong foundation he placed broken stone, like Macadam, decreasing its size up to the top, so as to avoid the roughness of Macadam's surface. Edgeworth had advised the filling of the interstices with gravel or sharp sand; and now all these plans are combined, with the addition of consolidating the material by using a heavy steam-roller, so that the surface, which has been sanded and watered, is made comparatively smooth at once. An up-to-date European road then has a Telford foundation, a Macadam center and a crushed, sprinkled and usually tarred surface.



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ON THE PEKIN PASS, THE HIGHWAY FROM MANCHURIA TO KOREA

The character of the roads of different countries and sections of these countries depends upon many things. Methods of financing, construction management, material available and the tastes of the people all have their influence. In the United States there are at least five different schemes for financing road-building, and, there being no National Road Board as in England, the management is in the hands of the individual state concerned. All countries have been forced to an awakening in matters of road construction and maintenance by the more extensive use of the automobile. Besides demanding more good roads, the motorist has vastly increased the cost of up-keep on the existing highways.

The material for a road in urban districts is chiefly determined by the amount and character of the traffic, and by the gradient. Where heavy vehicles slowly move great weights, as in the neighborhoods of docks and manufacturing plants, cobblestones, granite sets and coarse brick pavements are commonly found, the high construction cost being offset by a long life of usefulness. The gradient should be less than one in forty on account of the slipperiness of the surface during snowy or rainy seasons. On very severe gradients rougher stones such as cobblestones or gritstones must be used. Another objection to stone pavements cannot be overlooked: they are very noisy.

For the business part of towns and cities, wood paving or tar-macadam, varied as asphalt, has become almost universal, because of its cleanliness and noiselessness. The wooden blocks are usually treated with a preservative such as creosote, thus



STREET IN PARIS BUILT ON CONCRETE BRACKETS TO ADMIT OF RAILWAY WIDENING

increasing their length of life. In a busy thoroughfare they may be expected to last ten or twelve years if well laid. The cost of construction may exceed that of the softer varieties of non-slippery stone but the life of the blocks is somewhat longer. Tar-, or water-bound, macadam has a



THE DUST PROBLEM — RACING CAR PASSING FROM TARVIA TO MACADAM

much lower initial cost than the wooden block but the expense of up-keep is very heavy and its life relatively short.

In recent years roads made entirely of concrete have come into extensive use.

They give an almost ideal motoring surface. They appear to be durable though when badly worn they are difficult to repair except with some asphaltum mixture, which is also used to fill the cracks that eventually develop in them. In California concrete roads covered with a thin layer of asphaltum compound have been found to be very satisfactory. The famous Columbia River Highway in Oregon is a concrete road.

None the less, the tar-macadam road, or rather a macadam foundation with a bituminous binding on the top, frequently renewed, seems to be the road of the future, until chemistry invents a dustless surface-preservative that has less stickiness than tar. It has been found that a light dressing of a bituminous mixture will not only make a well-rolled macadam road quite dustless under motor traffic, but that the preservation of the surface of the road more than repays the cost of materials and labor when compared with ordinary renewals; and there is therefore no economic reason why all main roads should not be smooth and practically dustless under motor traffic.

The latest revival of the road in civilized countries began with the bicycle, a vehicle that has played quite a part in the improvement of social and economic conditions, especially in Europe. Then followed the motor car for business and pleasure purposes, at first content with light loads and low speeds, later to carry heavy loads and travel at excessive rates of speed. Eventually roads will provide for several distinct uses. The pedestrian must have his rights preserved by means of a foot-path free from dust. The vehicular traffic by animal draught must be respected and have its fair share of accommodation, and the motor machine of every kind has a right to demand a clear course of dustless road, so that it may be freed from the odium of creating a nuisance. In short, we are only at the beginning of the science of complete and adaptable road-making.

That science is now seen at its best in the two extremes of city life and mountain solitudes. The paving of many of our great cities with wood, asphalt, tar-macadam, dry macadam, gritstone, or granite,

SURFACING ROADS AND STREETS WITH TARVIA



PREPARING THE ROAD-BED: ROLLING THE FIRST COAT



APPLYING TARVIA ON WEARING COURSE BY HAND



Photos The Barrett Company

A TANK SPRINKLER APPLYING TARVIA TO MACADAM

according to the varying requirements of gradient, traffic and cleansing, is an example of masterly engineering and adaptation. At the other extreme are the magnificently engineered roads of the mountainous countries, and such isolated marvels as the motor road up Pikes Peak (14,108 feet) in Colorado. Some of the greatest of the Alpine roads were made, it is true, for military purposes, but they are kept up at heavy cost for peaceful ends, now that the original reason for their construction has disappeared. Thus the great road over the Stelvio Pass, be-

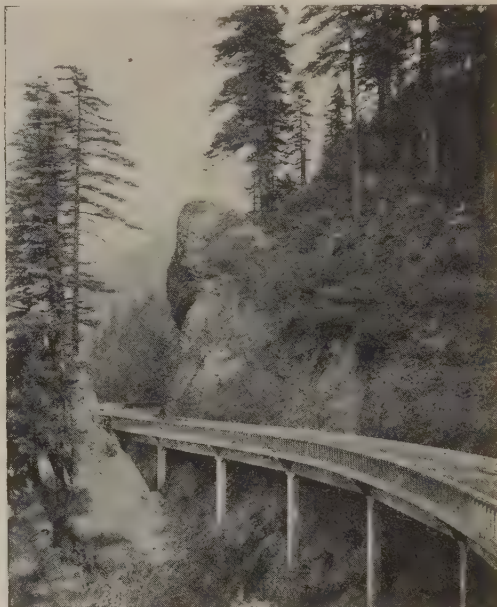
on the Italian side below the summit is much less precipitous, though lower there is repeated tunneling to avoid the dangers of avalanches.

Another great Alpine carriage-road that is highly characteristic is the Splügen Pass on the Italian side, where, by a series of galleries tunneling in and out of the rocks, an almost perpendicular face of cliff is descended. Among mule-trail passes the most noted probably is the Gemmi, between Kandersteg and the Rhone Valley, but the descent into Italy is so steep that riding is forbidden.



Photos Gifford & Prentiss

Eagle Crest of Wanna Mountain.



Tooth Rock and half bridge.

ON THE COLUMBIA RIVER HIGHWAY

tween the valleys of the Adige and the Adda, or Tyrol and Italy, was made by the Austrians as a means of retaining their hold on Venetia. The road, which crosses the snowline at a height of over 9000 feet, costs a great deal to reopen each summer. The repairs, of course, are incessant, and its full service is confined to about three months in the year. From the summit, looking down to Trafoi and the Tyrol, past the noble icy spire of the Ortler Spitz, rising sheer from the opposite side of the valley up which the winding road slowly creeps, seven miles of the zig-zagging ascent can be seen. The descent

The aim of engineers in planning a road is to keep it to a gradient of about one in thirty, with a similar cross-gradient, on either side, for drainage purposes. On such a gradient a horse with a moderate load can trot either up or down, but, of course, in mountain districts that slope often must be exceeded; and in many towns short-distance gradients are found as steep as one in eight or ten. In the case of the Stelvio Pass the rise from the valley of the Adige to the summit of the pass is over 6000 feet, up a continuous ascent of a little over sixteen miles, or an average of about one in fourteen.

MAKING A MODERN CONCRETE ROAD



HALF-WIDTH CONSTRUCTION, $\frac{1}{2}$ -INCH BAR REINFORCING, DEPTH 8 INCHES



FINISHING THE SURFACE WITH A BELT



Photos Portland Cement Association

ON THE LINCOLN HIGHWAY, A PERFECT TEN-MILE RUN

The need of such great natural highways for our vast country is obvious and we are slowly evolving a national policy to supply it. Originally road-making was a function of county authorities and

which the United States government may assist state road-building with grants of money, but subject to the creation, by the state taking advantage of such aid, of a responsible highway department. This act has greatly stimulated the good roads movement and today practically all of the states have such a department. Naturally, however, this has given rise to contradictory legislation, and in some instances to chaos, in the matter of the division of responsibility. It will take some time to evolve a perfectly logical system of joint federal, state and local control and up-keep. A few great national highways have already been projected and at least partially constructed. Of these there may be mentioned the Lincoln Highway from New York to San Francisco, the Jefferson Highway from New Orleans to Winnipeg, the Dixie Highway from Chicago to Jacksonville, and the great road which runs from Seattle to San Diego on the Pacific Coast. In some parts of the country the system of state roads has been well developed and most of our large cities can boast of well-paved streets.



Photo Gifford & Prentiss
TUNNEL ON THE COLUMBIA RIVER HIGHWAY

then, as traffic developed, it became something of a state function, cities, however, retaining control of their own streets. Finally the national importance of the question led to federal legislation under



Crandell joint spaces in place.

Pouring gutter expansion joint.

LAYING WOODBLOCK PAVEMENT

SPHERE OF GOVERNMENT ACTIVITY

Delimiting the Field of Political Action
and Determining the Policy of Government

HOW SHOULD POWERS BE DISTRIBUTED?

IN the preceding chapter we have referred to the tendency toward ideal conditions in cities. We are now to turn our attention briefly to some of the more general problems of government, particularly as they present themselves in America today, and as the progressive effort at their solution is illustrated in American history and institutions. This task falls naturally into two parts. In the present chapter we shall consider the first question as to what government in general, and the various governments of varying degrees of scope under which every individual lives, ought to undertake to do. After we have indicated the general lines along which this problem is to be attacked, we shall consider in the following chapter the second problem of how the government is to go about it to accomplish the particular tasks which are assigned to political organization; that is, the problem of administration.

The starting-point in all thinking about political and social problems is, of course, human wants and the effort to satisfy them. Right at the outset we are met by two opposing theories as to the very mainspring of political organization. The majority of thinkers in this field, beginning with Aristotle, have started from the premise that "man is by nature a political animal". By this is meant that there is innate in every human being a desire to associate and communicate, and perhaps coöperate, with other individuals. These thinkers explain the development of societies largely through the fact that men are inherently social creatures and like to be together and work together. We are thus assimilated to the social or gregarious

animals, and the basis of socialization is found in feeling, or in a primary instinct. On the other hand, a great American sociologist, the late Professor Lester F. Ward, sets out from precisely the opposite assumption. He contends that there is no inherent desire to associate, no "instinct of sociability", in the human species. Man is naturally a solitary animal, the largest natural aggregation being that of the small and temporary family group. In this view the evolution of society, and the development of the feeling of sociability itself as well, is due to the possession by man of intelligence, by which he perceives that through association he can much more effectively satisfy other wants. Association or socialization is thus explained as based upon the calculation of advantage to the individual, and not upon an innate disposition, feeling or instinct. Association in itself is supposed not to constitute a desirable end, but to represent a sacrifice, which is undergone for the sake of realizing other ends, purely individual in character, which are more important than the loss suffered through foregoing one's independence.

We need not here pass judgment from the genetic or historical standpoint upon the relative merits of these theories. But whatever may have been the *origin* of human association, many features of the development of political societies in the period of recorded history certainly seem to be better understood in the light of the second of the two theories. Whether or not association gratifies a primitive instinct, it certainly involves the sacrifice, in less or greater degree, of one of the dearest treasures of the human heart, *liberty*.

Thinkers may argue about the innateness of the instinct of sociability, but no one will gainsay the existence in man of the spirit of independence and love of freedom. It is equally clear that association does involve restraint; and the events of history show quite plainly that the extension in the scope and power of organized society has always been granted reluctantly, for the sake of securing obvious and important ends, when not actually forced upon men by irresistible compulsion.

Need of an external authority to enforce contracts actual and tacit

Here, then, we have the conflict of motives. Coöperative activity is the sole means of satisfying innumerable wants, and yet coöperation itself seems to involve restraint and to thwart the desire for individual independence. But this is not the worst of it. Only very limited results can be secured by *voluntary* association and mutual aid. Coöperation, to be effective, must be continuous and at least relatively permanent; the parties having once entered into it cannot be free to change their minds and withdraw again. There must be an external authority to enforce contracts and those quasi-contracts which one tacitly enters into in accepting the customary relations of life; and this means a further loss of freedom. To secure this external authority necessary to even primitive coöperation, the only practicable method yet devised is the establishment of a government having territorial sovereignty. That is, anyone born and continuing to live in a given region is compelled to accept the terms of common life which have been worked out by the people inhabiting it, unless he can induce the established sovereign power itself to change or suspend the laws until he can persuade enough of his fellows to overturn the authority by revolution. Although this means still more compulsion, it is inevitable, especially since the land must be disposed of in some orderly fashion. In practice this has been accomplished in every civilized community by the parceling out of land into private ownership generally continuing in the same families.

It hardly takes a Herbert Spencer or a Henry George to point out that men who no longer have the natural right of access to the soil on which all depend for a living are not free but are in virtual bondage. Yet history has shown that such a condition is necessary to any moderate degree of social coöperation; and, freedom or no freedom, it is better than the "war of each against all" so graphically pictured by Hobbes as the alternative to authoritative government and private property.

The first duty of government; "law and order"

All human life, all life higher than that of the "beasts that perish", is social and coöperative, and coöperation involves fixed rules which must be obeyed and will be enforced with penalties sufficient to insure general obedience. The first essential of human life is therefore a code of rules governing the various social relations, and the second essential is a means of enforcing these rules.

In the first place it matters relatively very little what the rules are, so there are rules and so they are obeyed. In various chapters of this discussion we have followed the development of "custom" and means of enforcing it. We have seen that the first sanction was superstition, the first ruler the priest. Primitive religion is in fact almost exclusively political in function, and it has never entirely lost this character; it still covers "duties to fellow men" as well as "duties to God", and includes obedience to the State as one of the principal virtues. It was in the first place merely the means of securing conformity to established usages, and conformity is what we mean by "law and order". In time a differentiation took place. More immediate, visible and tangible means were found for enforcing the more general and fundamental rules of the social life, — what we call the prevention and punishment of crime or misdemeanor, — and religion and the direct pressure of social opinion were left to regulate the more variable and detailed affairs and to form an additional sanction to the recognized law.

The kingly power

The first government was thus a king, not much differentiated from a priest, and remaining in the closest partnership with the elder functionary. It is wrong, however, to think of the first king as an absolute monarch. Theoretically he might be so, but in fact he was about as closely bound by custom as anyone else. He was undoubtedly much more of an executive than a legislator. Here, however, the tendency of change was in the king's favor. One reason for the development of his power was his extreme usefulness in time of war, which is the principal occasion calling for effective coöperation in a primitive people. It should be understood that the primary function of government, the enforcement of law and order, a king may perform exceedingly well. The very evident social utility of obedience to the king, while he keeps in his proper sphere, aided in the growth of the idea, carefully fostered by the king himself of course, that the will of the king is itself the law.

Some practicable provision for changing or making law, as well as for enforcing it, a society must have if it is to progress at all, and for a long time the king may very possibly have performed this office also. However, it naturally was here that he broke down, and his failure as a law-maker gave rise to modern forms and theories of government; probably it even stimulated the first deliberate thinking that men ever did on the question of what a government is for and what it ought to be like. Previously they seem to have accepted the king unquestioningly as the divinely ordained institution he pretended to be.

The law-making function. The idea of a popular will

Laws, as we have seen, were originally not made at all; they were the primeval usages of the people, — customs, which just naturally grew, Topsy-fashion, without thought, plan or purpose. Really, as remarked above, it was a matter of secondary moment what the rules were which governed social relations, but it was absolutely necessary that there be rules.

But in general, usages which survived had to be tolerably suited to a people and its conditions of life. Our own Common Law, inherited from England, is still supposed to go back far beyond all deliberate or authoritative legislation to the customs of the barbarian Germans in the forests of the Rhine and Elbe, though this is apparently in large part a myth. It is questionable how much of it is older than the Norman Conquest of England, and probably most of it could be traced to a "statute" or to the *ipse dixit* of some judge. In a more real sense, perhaps, the Civil Law or Roman Law which forms the basis of European legal systems, goes back to the *jus gentium* or "law of the peoples" which the Roman lawyers claimed, to find underlying the varieties of law among the multitudes of their subject nations.

Kingship always breaks down when people realize selfishness in king's mandates

When societies came to move about, to grow, to conquer other groups, or learn new modes of life, usages or laws had in some way to be made to fit new conditions, and growing intelligence also demanded their improvement. Primitive groups no doubt held their customs as eternal and sacred, as ends in themselves and not to be questioned. But it would not be so with the arbitrary orders of a king, probably even if all of these were obviously good. Even so they would lead men to think about the utilitarian bearings of institutions; and if, as soon came to be the case, many of the king's statutes were obviously bad, the subjects would no longer consider the situation tolerable. A people of even limited intelligence will not long regard as sacred mandates which can be seen to aim at the exploitation of themselves in the interest of the ruler's selfish ambitions or personal advantage. And here is where kingship always breaks down. From the standpoint of efficiency in enforcing generally accepted law, it is hardly to be criticized, and it may do tolerably well as a means of meeting new situations. But kings, by bringing their own aims and purposes into conflict with those of the people whom they govern, never fail to

make the people whom they govern conscious of their own wishes, to cause them to reflect on the function of government and to come to see legitimate authority as the means of realizing the popular will. Pre-war Germany was the only modern nation which had in any degree kept the conception of the State as an overbeing with a life and purposes of its own to which those of the individual may properly be made subservient. In that country this naïve, implicit view of the primitive State was consciously retained and developed into a political theory. In all the more liberal nations, on the contrary, reflection on political questions has invariably led to the other view, that the State is a means only, that its function is to provide the structure of coöperation between individuals in the achievement of their common or mutual ends.

The final step. The theory of democracy. Meaning of political "liberty"

Gradually and as the result of a long struggle, with many ups and downs, the English people, the authors of modern national democracy, got the law-making power into their hands. The result was achieved, as everyone knows, through the control of the people and their representatives over the granting of money to the government. The personal income of the monarchs became less and less adequate to the needs of government and it could not effectively levy and collect taxes without popular support, which had to be secured by adopting policies which the people approved. Thus England gave to the world the theory of democracy, which we have already sketched. From the standpoint of efficiency, which means getting things done, monarchy is unexceptionable. But when it comes to the question of the things which the government is to get done, they must be the purposes of the people and not the personal ends of the ruler. The people cannot permit themselves and their resources to be used for ends which are not their own, nor can they allow an accidental hereditary potentate to be the judge of their welfare and the proper means of securing it.

Difficulties in the ways of completely divorcing executive and legislative functions

For the execution of policies after they were popularly determined, the English long retained monarchy. Here the system makes its strongest case, and here also democracy is weakest. But the logic of the situation demands that the people have at least ultimate control over the administration as well as the formulation of law. There cannot be a permanent and complete division of the functions of government, and in all free or democratic nations today the executive as well as the law-making officers are popularly chosen and controlled. In England the king no longer appoints, in anything but a formal sense, the ministers who are the chief executive officers of the government; he is in fact more of a symbol of unity and continuity in the State — like the flag or the great seal — than a government official at all. It is to be noted, however, that experience has proven it unwise to bring the executive branch into as close touch with the people as both expediency and the safeguarding of their interests require in the case of legislation. The best political opinion of today would favor bringing the legislative branch as close to the people as possible or practicable, and keeping the executive as far away as is consistent with securing harmony between the two divisions. Our "Independent Judiciary" is a measure looking to this end, as the Judiciary is really executive or law-enforcing in function although organized in the United States as a coördinate department alongside the Executive and Legislative.

The theory of democracy is thus the recognition that government is an agency for reënforcing the "people's will", which means merely regulating that compulsory coöperation on which all civilization rests along the lines and directing it to the ends which the citizenship desires. It is really the only possible conscious theory of government, for we cannot see how the German view of the State as a super-entity with purposes of its own superior to those of its citizens can be consistently held.

It seems to be but a question of time and the development of the requisite popular intelligence for all the nations of the world to go over to thorough-going, out-and-out democracy.

Democracy is the meaning of political or civil liberty, or at least it is the best meaning to be given to that term. It does not therefore mean at all that such government involves no sacrifice of individual independence. It means only that each individual has an equal voice, or that his interests are equally regarded in making the laws, which are impartially enforced. He is in a sense compensated for his loss of freedom by his share in constituting and directing the power which all must obey, and in addition he secures the blessings of civilized life, which could not exist without government.

The great expansion of governmental activities in modern times

The primitive powers of government are the police power and the war power, the preservation of peace and order at home and defense against foreign aggression, and these powers are carried into effect first by the enforcement of ancient customs and later by the making and enforcing of laws. These original powers, however, contain little more than a suggestion of the multitudes of things which a modern State does for its people and we must now survey the process by which the mere administration of justice has grown into the vast and varied governmental activities of today. For the moment we shall still consider political organization exclusively as the means for achieving purely individual purposes. This is no longer the whole truth, if it ever was, and we shall presently have to take account of some effects of association itself becoming an end and differentiating into group ideals; but it is still true that private purposes predominate and that group action is largely a means to their fulfillment.

The first cause, then, for the expansion of governmental functions, is the fact that the scope of social coöperation in the satisfaction of wants has greatly widened.

There are many phases of this complicated change, but perhaps most of them are summarized under the head of industrial progress. As everyone now understands, the principal mode of coöperation in civilized life is through division of labor and exchange, or economic organization. The greatest change that has taken place in human affairs in modern times is the drawing of people together through the discovery and invention of new ways of producing things which require the working together of great numbers of people, often widely separated, to supply the needs of a single individual. The efficiency of labor has been increased many fold by the use of machinery and by specialization or narrowing the range of tasks which any laborer is called on to perform. The result is both a vast increase in the size of what we may call the self-sufficient unit and in the amount of dependence between its parts.

In primitive times a single family might be largely self-sufficient, producing the greater part of the things it consumed, and calling on other families for little, while a small neighborhood would be almost entirely so. Only a few small classes of men, such as the producers of metals and other things which occur but occasionally and then not in agricultural regions, have always been specialized and lived by exchange.

At the present time all this is very different indeed. Only a few families produce any considerable part of what they use; the farmers are the one large class who even produce completed things for exchange or sale for others to use. The majority of the workers in a modern industrial nation are performing merely some one process in the making of a small part or piece of something; the individual product of one of them cannot be separated, hardly identified, much less used. And they do not do that independently or on their own account. More and more of us live by selling merely our time and services to a small number of responsible producers each of whom in turn is connected with performing a small part or a mere stage in the completed good.

Changes that have come about by the methods of modern industrialism

The result is that a working man may pass his active life and make a comfortable living without ever turning his hand to the production of a single object which he or anyone of his acquaintance will directly or indirectly use. At the same time, many thousands of workers, scattered over the wide world, must work together to provide for the daily wants of this humble working-class family. Consumption is nearly as complicated. A single workman may control the machine which rolls steel ingots into the railroad rails over which millions will ride before they are discarded, and which will carry letters and merchandise for millions more.

In a society with such an organization as this, the conditions of coöperation become numerous and complicated; there is hardly a limit to what "law and order" may include. Every person's comfort, often his life, is dependent on the working in a reasonably smooth and efficient way of the system as a whole. Government is the only agency suited to guarantee this result, and government must be organized and given the requisite powers to accomplish it, both within and without the nation, for the system has become in many respects world-wide. Under these conditions the individual must often very largely give up his right to "do as he will with his own", to work or not work as he pleases or to hire or not hire whom he will and on what terms. The increase in the efficiency of want-satisfying activities is as always purchased with a loss in individual freedom.

Liberalism's change of front, from "laissez-faire" to governmental direct action

We have described the growth of democracy as a reaction against personal government which had claimed absolute authority and turned its power to personal instead of national ends. Down to a few centuries ago political power was restricted to kings and a small circle of nobles or landed aristocrats, or in the "free" towns of Europe to a narrow aristocracy which

controlled everything through the guilds, and used its power very selfishly. The maintenance of order was interpreted to mean the maintenance of the *existing* order, and the chief work of government seemed to be the perpetuation of the special privileges of the few. To this end, commerce, occupations and the prices of goods, as well as the succession to all places of power in the State itself, were subject to the most minute regulation. Everything was ordered on the general principle of "status", *i.e.*, that everyone must keep the social position and scale of living into which he had been born.

To try to improve one's position once almost criminal in other countries

In such a state of affairs the natural contention of liberal opinion was for freedom from restrictions, for equality of opportunity and advancement according to achievement and merit instead of the hereditary status. The dawning of the modern era in the Renaissance and the Reformation brought a new appreciation of the individual as such, while the awakening of the commercial spirit and discovery of new lands where limitless opportunity beckoned to enterprise called forth the spirit of adventure and competition. "Every man his chance" came to be the watchword, instead of contentment with the lot in which the accident of birth had cast him. It is hard for a modern American to realize that until recently even in the most civilized countries it has been considered positively criminal for anyone to attempt to improve his position in life.

Competition, free enterprise, the removal of restrictions and handicaps, were especially called for in settling the New World, developing world trade and improving production processes through invention along modern lines. The doctrine of narrowly restricting the activities of government and particularly of not allowing it to interfere in industrial relations, developed rapidly in the eighteenth century and after, and came to be the gospel of Liberalism. It was promulgated in France under the name of "*laissez-faire*" (let alone), a phrase which has been

taken over into English. The doctrine was elaborated into a complete social philosophy and ably defended by Adam Smith in the "Wealth of Nations" published in 1776. By the middle of the nineteenth century virtual free trade was secured in England and the "*laissez-faire*" theory was completely dominant. Although, as we have noticed in previous chapters, much suffering was entailed in the transition through the "Industrial Revolution" to the modern system, yet the theory seemed on the whole to be justified by its fruits. The efficiency of labor had been multiplied many times and the wealth, population and power of the country increased several fold, while the lower classes had also benefited in a higher standard of living and access to luxuries which princes could not have obtained a century before.

No sooner was new freedom obtained than exceptions were imperatively demanded

Nevertheless, freedom from governmental interference had not been fully established before exceptions were imperatively called for and had to be made. Children especially had to be protected by factory acts from an exploitation which would soon have sapped the vigor of the race. Many adults also proved incapable of holding their place in the competition, and modern nations have an appalling problem of pauperism to deal with. Moreover, freedom of action was soon found to involve freedom of combination and united action, though the industrial leaders who most ardently advocated *laissez-faire* were very reluctant to concede this to the working men. As time went on employers and employees in whole industries have been welded into effective organizations, capable in such vital services as transportation and coal-mining of paralyzing the whole industrial system, a fact which the American people were brought to realize by the threatened railroad strike in 1916, a nation-wide coal miners' strike in 1919 and strikes in both the railroad and mining industries in 1922. These services have everywhere to be controlled and regulated by government, as we have been doing for the railroads more and

more effectively since the Interstate Commerce Commission was established in 1887. Many governments have reached the conclusion that the only practicable way to guarantee the continuous functioning of such industries is for the public to own them and operate them through the administrative machinery of the government. It is a matter of political expediency only, not subject to determination by general principles, what services shall be brought into the sphere of compulsory coöperation and which ones shall be left to the more voluntary coöperation of private enterprise. The number of industries over which the public interest demands some supervision of methods, and the amount of the control to be exercised, both tend to increase rapidly.

Complete reversal of liberal opinion on question of governmental interference

With a government representative of the people, dedicated to their interest and amenable to their control, there should be no danger in committing to it any functions which affect most of the people in the same way. The people of the democratic nations have begun to realize this fact and instead of being wary and suspicious of governmental actions and intentions are calling on it to do more and more things for them. Government is becoming less an external authority for securing the conditions of voluntary coöperation and more the direct agency of coöperation. In particular it is expected to do for the poorer people, who now hold the balance of power in the electorate, many things which they are unable to do for themselves through free competition. Liberal or progressive opinion has thus practically reversed its position on the question of governmental interference. It wants the government to adopt a positive, constructive policy, not merely to provide the conditions for its citizens to do things for themselves, but to do things for them, or more strictly to displace increasingly other modes of coöperation and itself become the principal organization through which the people achieve common purposes.

New lines on which government is striking out to provide for general welfare

The leading European countries, being older than America, much more densely populated and relatively more industrialized, have felt the pressure of new needs sooner and more urgently than have we. The danger of war has also acted upon them as a strong force making for national integration. In France and Germany the railways and telegraphs are owned or directly controlled by the governments, and in England this is true of the telegraphs. Public utilities, such as street railways, telephone systems, gas and water supply, and light and power plants, are commonly owned by the municipalities which they serve. These nations have also established insurance systems which partly by compulsory levies upon employers and the working people themselves, and to a considerable extent by contributions from general taxation, protect people from want through loss of earning power in industrial accident or sickness, and provide medical attention also. They have gone farther still in trying to provide decent living conditions. Not only do stringent regulations control all new building in cities with reference to sanitation, safeguarding against fire, prevention of overcrowding, access to light and air, etc.; even the sightliness and harmony of buildings are taken into account.

With the crowding of large populations into cities and the much greater mixing and mingling of people which have come with modern means of transport, the danger of transmitting disease is enormously increased. Under modern conditions the individual cannot be granted the right to be sick or careless about his health. The question of establishing a National Department of Public Health on a par with the other executive departments and headed by a member of the President's Cabinet has long been agitated. All progressive communities now have a public health officer, strict quarantine laws, compulsory vaccination, etc. In later chapters some description of what is being done for public health will be found.

Even a hundred years ago it was hardly considered anybody's business except one's own whether anyone were ignorant or educated, wise or foolish, so long as he looked after his affairs sufficiently not to become a charge on the public. With royalty and aristocracy in control it was even considered something of a misdemeanor to attempt to educate the lower classes or encourage them to try to rise out of "their station". This view is said to be still held by many wealthy people in England, where public education is backward in comparison with some other countries; learning is supposed to make laborers and servants "uppish" and impudent to their "betters". In America, however, and generally in democratic countries, it has long been realized that a free government can hope to succeed only with an electorate educated to an intelligent interest in political questions and sensible ideas for dealing with them. Accordingly ignorance also, as well as disease, has become a sort of social crime. Elementary education is universally free and generally compulsory; many communities also furnish text-books and some provide lunches for underfed children at school. Some American states provide practically free education clear through the graduate schools of their universities which are equipped and maintained on a par with the best privately conducted institutions in the world.

Broadening sphere of common purposes demands increasing centralization

There is a feature of the extension of the field of coöperation which gives rise to peculiar difficulties in American political theory and practice just now. At the adoption of the Constitution legislative power was rigidly parceled out between the states and the national government, the states receiving much the larger share. Political efficiency and progress have always been handicapped in this country by the vices of separatism, individualism, localism and sectionalism, and the effects are seen in the division of powers in the fundamental law. It was only the serious failure of a much worse arrangement, the Articles of Confederation, giving the cen-

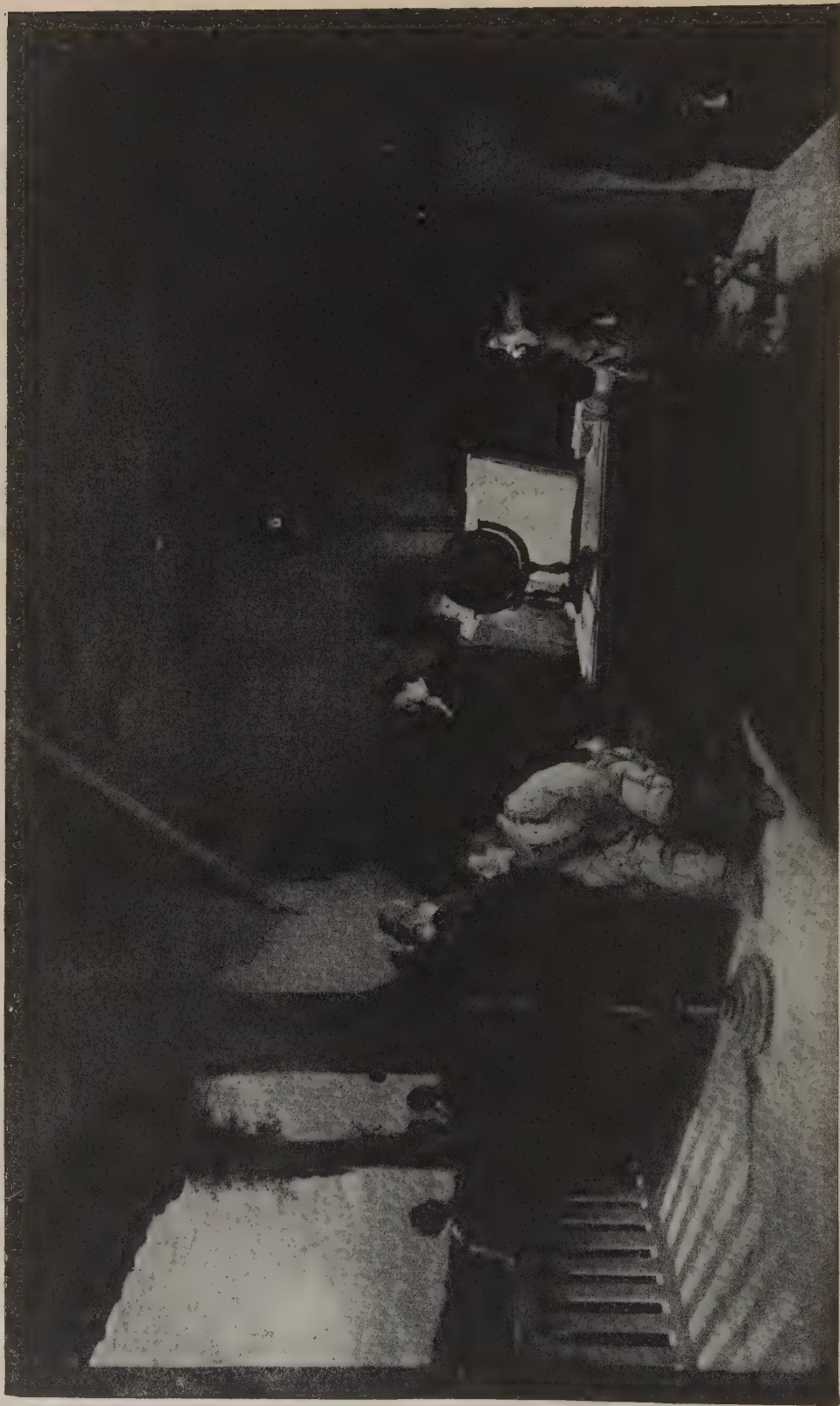
tral government almost no real power at all, to which we owe as effective a general government as we have. America was then a frontier nation of some three million souls. In the one hundred and thirty odd years which have passed since the Constitution was adopted we have grown to more than a hundred millions and become one of the great industrial nations of the world. In consequence of the changes taking place in that period, some of which we have sketched above, men are as near neighbors in many respects to other men in different states as they were to those in the same county or town at the close of the Revolution. As a result, the field over which uniformity in legislation is desirable is much wider than it was then, and the evil which comes from diversity much greater. To bring the distribution of powers between the federal and state governments into line with modern requirements would require an extensive remodeling of the frame of government, which it is impossible to secure. The Dominion of Canada, organized in 1867, and the German Empire, founded in 1871, were forewarned by our difficulties and gave the general legislative power in both the civil and criminal law fields entirely to the central government. In this country some progress has been made by voluntary coöperation between the states. The Conference of Governors instituted by President Roosevelt has helped, and private organizations have drafted many "model laws" to be adopted by the various states. It would seem, however, that such extra-official expedients must be only temporary makeshifts and that formal changes cannot long be postponed. The power of the national government has already been vastly increased simply by more and more liberal construction of the Constitution by the Supreme Court, and in one case, that of the income tax, a constitutional amendment has been secured.

The distribution of authority between local and central agencies is a very difficult problem in constitution making. Men coöperate for different ends in groups of widely varying size, and with changing

conditions of economic life the scope of all these areas changes also. What seems to be needed is a more flexible adjustment than we now possess. Cities and local communities are rightly calling for more "home rule" at the same time that national consolidation in industry is forcing more power into the hands of the supreme central authority. Apparently the states must continue to diminish in importance, losing functions on one side to the nation, and on the other to the small locality. They never were particularly logical divisions, nor have their governments generally shown themselves strikingly competent in dealing with their problems.

A new kind of coöperation. Ideals of common life

Before leaving this subject a word should be in place by way of recognizing that political organization is not in fact at the present day *merely* a means to the realization of purely individual purposes. Whatever may have been true originally, men have come to value association with their fellows for its own sake and to cherish more or less definite ideals of what such association should be like. Thus we can speak of political ideals which are more than opinions as to the effectiveness of particular arrangements in enabling individuals to get things that they want. We can recognize a new kind of "group will", which is not what individuals in the group want from the group for themselves, but what they want the group itself to be and do as an entity. We do feel pride or shame for our community and our nation; we are exalted or humiliated by the knowledge of what it is and does, irrespective of any difference it may make in our own lives or any credit or discredit cast upon us personally. Sentiments of this sort, whether inherent in human nature or themselves generated by association and group activities, are real and must be reckoned with. They make a great deal of difference in concrete problems of government, and under the name of "patriotism" constitute the principal background of all thinking in the sphere of international relations.



GALILEO SHOWING TO JOHN MILTON THE MARKINGS ON THE MOON, AS SEEN THROUGH HIS NEW TELESCOPE

ASTRONOMERS IV

GALILEO—THE DISCOVERER OF THE LAWS OF MOTION

SIR DAVID GILL—THE SEARCHER OF THE SKIES FROM SOUTH AFRICA

GEORGE ELLERY HALE—INVENTOR OF THE SPECTROHELIOGRAPH

EDMUND HALLEY—PREDICTER OF COMETS AND MANAGER OF NEWTON

SIR JOHN HERSCHEL—A MOST TIRELESS "SWEEPER OF THE HEAVENS"

SIR WILLIAM HERSCHEL—THE BREAKER OF THE BARRIERS OF THE SKY

CAROLINE HERSCHEL—A GREAT MAN'S GREAT SISTER

HIPPARCHUS—THE GREATEST OF ANCIENT ASTRONOMERS

SIR WILLIAM HUGGINS—THE PIONEER OF ASTROPHYSICS

CHRISTIAN HUYGENS—ASTRONOMER WHO MADE CLOCKS AND TELESCOPES

GALILEO

Discoverer of the Laws of Motion

GALILEO GALILEI was born at Pisa on February 18, 1564. He belonged to a noble family of Florence, whose original surname was Bonajuti, but who took the name of Galilei in 1343. Members of this family had filled many positions of honor in the state, but Galileo's father, Vincenzo de Bonajuti de Galilei, though a cultivated man, a musician and mathematician, was very poor. He desired, therefore, that his son's studies should be, unlike his own, in branches of learning which might prove materially remunerative, and Galileo, at seventeen years of age, was sent to the University of Pisa to study medicine. Up to this time he had been at school at the monastery of Vallombrosa, and had shown himself not only to be a quick and intelligent scholar, but also to have considerable taste and aptitude for poetry, music and painting.

His father, knowing by experience that mathematics were a peculiarly unremunerative form of study, endeavored to prevent Galileo from becoming versed in them, for already, as a boy, his skill in devising mechanical toys showed that he had inherited considerable ability in this direction. However, early in 1583, Galileo, straying into a lecture on Euclid, became fascinated with the subject and began to devote all his spare time to it. His own disinclination to pursue the study of medicine and the difficulty which his

father found in paying for his college education, added to the fact that his independent and argumentative disposition made him unpopular with the authorities, resulted in his return, in 1585, to his father's house at Florence. Here Galileo pursued the study of mathematics with ardor and, in 1589, after several vain attempts to secure a similar position, was appointed lecturer in mathematics at the University of Pisa. His salary was absurd—sixty scudi a year, or about \$65 of our money.

He was obliged to leave Pisa on account of the storm of hatred aroused by his discovery and teaching of the laws of falling bodies. Aristotle had taught that bodies fall in a time proportional to their weight, but Galileo showed, by dropping various bodies from the Leaning Tower of Pisa, how false this assumption was, and stated the real laws of falling bodies. This discovery is the most important of all Galileo's contributions to science, for upon the laws of motion which he expounded the whole science of kinetics, as now understood, virtually rests. But it lost him favor and position, so unwilling were the mathematicians to be convinced by demonstration against accepted authority.

In 1592 Galileo was appointed professor of mathematics at Padua University for six years, and this appointment was twice renewed, so that he retained the position until 1610. In 1597 he invented his proportional compasses, the earliest representative of the sextant.

In 1604 the appearance of a brilliant new star in *Serpentarius* gave Galileo the opportunity of launching his shafts against the accepted astronomical theories. He attacked first of all the Aristotelian teaching, universally held at that time, as to the unchanging and incorruptible character of the heavens; and proceeded, with all the fervor and probably much of the bold assumption of the new convert, to set forth the Copernican system of the heliocentric universe, and to repudiate the Ptolemaic or geocentric system. In 1609, hearing of the invention of a Dutch optician for bringing distant objects near, Galileo in one night succeeded in working out the principle, and at once set to work to construct a telescope and, having produced a satisfactory one, turned it towards the heavens, with results which in his day were truly astonishing. For the first time sun-spots came to sight, supplying Galileo with a powerful argument against the doctrine of immutability, and by their movement across the face of the sun indicating its rotatory motion. With it, too, Galileo discovered Jupiter's satellites, and proved the truth of Copernicus's assertion that, if we could but see them clearly, Venus and Mercury would be found to show phases similar to those of the moon. Galileo was triumphant. Overwhelming proof seemed to him to be now provided both against the Ptolemaists and against the supporters of the theory of immutability.

The telescope was Galileo's most famous gift to science, though it really was not so important as his discovery of the laws of motion; for the telescope would inevitably have been improved and turned upon the heavens — which was Galileo's share in its discovery — before long, even without him, whereas it is unlikely that the laws of motion would have been truly expounded for some time to come.

It is frequently supposed, by those unfamiliar with the more recent historical investigations on this subject, that the Church had set her face utterly against scientific progress, and in particular against Galileo's discoveries. It is certain, however, that, in the year 1611 Galileo visited

Rome, and was received with great honor by Pope, cardinals and priests. His telescope was set up in the Quirinal garden, the property of Cardinal Bandini, and crowds of curious and interested spectators were allowed to come there and look through it. Trouble certainly arose, however, when Galileo, always assertive and dogmatic, rendered arrogant by his fame and success, went beyond his own sphere and maintained that Scripture was on his side. In order to realize how dangerous such an assertion appeared to ecclesiastics to be to the faith of the people, we need to remember the familiar association between the Scriptural accounts and teaching and the accepted Ptolemaic system, which, however scientifically false, still remains descriptively true as a mere explanation of appearances. It is said in defense of the Church that it was ready to listen so long as Galileo confined himself to teaching the Copernican system merely as a hypothetical explanation, which it was for future science carefully to determine by observation and inquiry, but that when Galileo asserted it as absolute truth and as the real teaching of Scripture, they repudiated and condemned his teaching. The proofs which were at that time adduced in support of the Copernican system were by no means eminently satisfying, and many of them are now known to be false. On such inadequate grounds a theory of the universe was boldly proclaimed to the people which was almost certain to result in undermining their faith, since to the ignorant mind it impugned the authority of Scripture. The Church was not concerned with questions of science still manifestly theoretical; she was deeply concerned in the faith of the people. Hence Galileo got into trouble with the Church. We are told that he was accused before the Inquisition in 1615, but at that time the result was that he was merely recommended to confine himself to his mathematical reasonings upon this system, and to abstain from meddling with Scripture.

Galileo apparently submitted. He undertook to put forward the Copernican theory merely as hypothesis, and for some

time he adhered to the letter of his promise. But the irony, clever and biting, with which he wrote showed that an unsubdued hostility chafed within him. He produced a paper on the tides, which for him supplied the strongest argument in favor of the Copernican system, now, of course, known to be quite false. In 1618 three comets appeared, and in 1619 Galileo published his theory of comets, which he regarded as of similar nature with halos and rainbows. At the same time the Jesuit Grassi delivered a course of lectures, explaining them as heavenly bodies.

It has been noted by one of his biographers that Galileo never, throughout his whole career, put forward a theory which was not remorselessly and bitterly attacked. This is not so astonishing when we consider with what ridicule and violence Galileo himself attacked Kepler's lunar theory of tides and Grassi's heavenly theory of comets, both of which were, in fact, true, and with what animosity he carried his war into the camp of his opponents often without reason or justification.

In 1624 Galileo again visited Rome and was cordially received, but failed to obtain, as he wished, a reversal of the judgment of the Inquisition. The new Pope, Urban VIII, had, as Cardinal Barberini, been one of Galileo's warmest friends and the astronomer seems to have expected that all would now go as he wished. He published an ironical discussion of the various theories of the universe, "*Il Saggiatore*," which the Pope enjoyed, and, rendered over-bold by this success, brought out his "Dialogues" on the systems of the world (1632), in which, under the flimsiest veil, he boldly stated the case for the Copernican system. A supposed insult to the Pope, which Galileo certainly never intended, told against him. He was tried by the Inquisition, made a formal abjuration of his scientific theory, and retired to his villa at Arcetri, near Florence, a broken and disappointed old man. He died on January 8, 1642.

A movement has recently been started in Rome to make the house at Arcetri, called "Jewel", a national monument, and to collect there all Galileo relics.

SIR DAVID GILL

The Searcher of the Skies from South Africa

DAVID GILL was born in Aberdeen on June 12, 1843, and was educated at Marischal College in that city. His devotion to the study of astronomy developed early, and he constructed an observatory in his father's garden. In 1873 he was put in charge of the private observatory of Lord Lindsay at Dunecht, a post he held for three years. Here he was responsible for all the arrangements of Lord Lindsay's expedition to Mauritius, in 1874, for the observation of the transit of Venus. In 1877 Gill organized a similar expedition to Ascension to observe the opposition of Mars, and, from the measurements then obtained, determined the distance of the sun at 93,080,000 miles. For this valuable work he received the gold medal of the Royal Astronomical Society in 1882.

In 1879 he was appointed Astronomer Royal at the Cape of Good Hope, a position he occupied for twenty-eight years, and from 1881 he devoted considerable time to the investigation of stellar parallax, securing more exact results than anyone else had yet succeeded in obtaining.

In 1886 Dr. Gill was responsible, jointly with M. Mouchez of the Paris Observatory, for bringing about a congress of astronomers to arrange for the construction of a complete chart of the sky by international coöperation. He pointed out the value of photography in this work.

Between 1880 and 1896 Dr. Gill organized and brought to completion a geodetic survey of Natal and Cape Colony. He was also engaged in several other surveys. He died January 24, 1914.

Many honors were conferred upon him in recognition of his services to astronomy. In 1896 he was created a C. B., and in 1900 was knighted. He received the recognition of many European and American learned societies. He took a considerable part in the foundation of the South African Association for the Advancement of Science, and was its first president, in 1903. He published a number of books on astronomical subjects, written for serious students rather than the general public.

GEORGE ELLERY HALE
Inventor of the Spectroheliograph

GEORGE ELLERY HALE was born in Chicago in 1868, and at the age of eighteen entered the Massachusetts Institute of Technology, graduating in 1890. Before he had finished his course there, however, he had erected a spectroscopic laboratory behind his father's house. His education was continued at the Harvard College Observatory, and at Berlin. In



GEORGE ELLERY HALE

Taken at the spectrograph of the 60-foot tower telescope of the Mount Wilson Observatory while photographing the spectrum of a sun-spot for the purpose of studying its magnetic phenomena (1908).

1891 he became professor of astrophysics at Beloit College, later associate and (1897-1905) full professor at the University of Chicago. In 1893 he was asked to plan the Yerkes Observatory, which contains a 40-inch refracting telescope, the largest instrument of its kind in the world. It was no easy assumption of duties that fell to the director of Yerkes after its dedication in 1897; the preceding years had been full of weeks and months of the end-

less and often petty details incident to great building operations, and of slow securing of funds for them. After delays and discouragements, Charles T. Yerkes, of Chicago, who agreed in 1893 to give the money to buy the glass, had been induced to provide additional funds to build the telescope and erect the observatory at Williams Bay, Wisconsin, and Hale himself secured the funds for numerous other instruments.

The project of founding a solar observatory was considered in the early days of the Carnegie Institution of Washington, and a committee, of which Hale was a member, reported a plan of action. This involved the expenditure of more funds than were available at that time and the plan was dropped. It was revived, however, when in 1904 Hale with characteristic energy raised money and began work in a modest way on the then almost inaccessible summit of Mount Wilson, a peak about 6000 feet high near Pasadena, California. Recognizing the promise of the work thus begun under most favorable climatic conditions, the Carnegie Institution renewed its interest in the project, and has since provided amply for its execution.

Offices, laboratories and instrument shops were built in Pasadena itself, and the telescopic and other apparatus set up on the summit of Mount Wilson. In the observatory knowledge derived from the study of the sun, the only star near enough to the earth to be examined in detail, is applied to the interpretation of stellar phenomena. In the laboratories, which are equipped with special instruments for the purpose, the experimental imitation of celestial phenomena is carried on for purposes of interpretation.

On Mount Wilson the first instrument erected was the Snow horizontal telescope (see *Conquering the Sun*, Chapter 16, Group VIII, Power, p. 2109), used daily to photograph the sun, with Hale's own invention, the spectroheliograph. This instrument enables the operator to photograph the sun with light which comes from a single element such as calcium or hydrogen; with it, it is now possible to photo-

graph not only the eruptive prominences on the sun but also the great cyclonic storms, or vortices, discovered with this telescope in the sun's atmosphere. The detection of these whirling storms led Hale in 1908 to the discovery of intense magnetic fields in sun-spots and to the recognition of the true nature of the sun-spots themselves. In the eruptive prominences masses of gas far greater than the earth in volume are thrown up from the surface of the sun to a distance greater than that from the earth to the moon.

The observatory possesses a 100-inch reflecting telescope, the largest in the world, for stellar research, and a 60-inch reflecting telescope, likewise used for the photographic study of stars and nebulae. There are two tower telescopes, a new type of instrument devised by Hale, one of 150 feet total length with a 75-foot spectrograph and spectroheliograph, which is mainly used to investigate the magnetic phenomena of sun-spots and the sun as a whole; and one of 60-feet with a 30-foot spectrograph and spectroheliograph for the study of gases at various levels in the solar atmosphere.

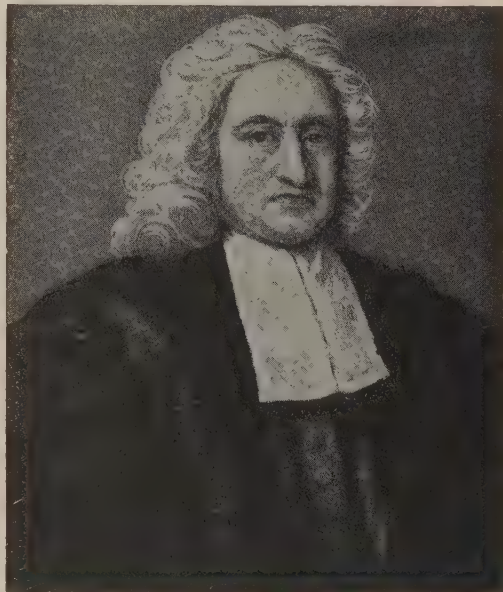
Recently, with the larger tower telescope, Hale has made one of the most important solar discoveries of modern times, namely that the sun is a vast magnet, and by measurement and calculation he has determined the strength of the sun's magnetic field.

Planning, building and directing two great observatories, and in them making valuable research, and advancing the cause of science do not constitute the sum of Hale's energies. In 1895 he established the *Astrophysical Journal*, and from his pen have come many contributions to scientific problems of the day. In 1904 he organized the International Union for Coöperation in Solar Research and in 1916 the National Research Council of which he is now honorary chairman. He is also a member of the executive committee of the International Research Council, as well as a member of the leading scientific societies of the United States and Europe, and has received numerous medals for his astrophysical achievements.

EDMUND HALLEY

Predictor of Comets and Manager of Newton

EDMUND HALLEY was born in Shore-ditch, London, on November 8, 1656, the son of a rich soap-boiler. At school he was a brilliant student, taking honors both in mathematics and classics, and showing an interest in astronomy. When he went to Queen's College, Oxford, in 1673, he took with him telescopes and other instruments, and in 1675 had already contributed to the Royal Society a most ingenious paper on the motions of the planets.



EDMUND HALLEY

At this time Flamsteed, with the patronage of Charles II, was engaged in making a catalogue of stars, a work in which Hevelius was also occupied. Halley, as a young man of twenty, deeply concerned with planetary motions, was impressed with the value which a similar catalogue of stars in the southern hemisphere would have. Gaining the ear of the king, he procured the money for an expedition to St. Helena, and in 1676 set out to accomplish this design. He succeeded in cataloguing nearly 350 stars, but his work suffered from difficulties of misty skies and an undue precipitancy in his own methods, which sometimes led him to publish results before thoroughly check-

ing them. It was, however, a brilliant feat for a young man. Besides obtaining his catalogue, Halley secured on this journey observations of the variation of gravity in different latitudes, and witnessed a transit of Mercury. In 1678, on his return, he was made a fellow of the Royal Society, and received the M.A. degree of Oxford by special command.

In 1680, traveling to the Continent with a friend, Halley saw the Great Comet and, proceeding to Paris, made observations of its orbit with Cassini. This was not the comet associated permanently with Halley's name; that appeared in 1682.

In 1681 Halley was in Italy. In 1682 he settled in London. His time now was chiefly devoted to studying the moon's orbit, and after two years of continual observation he was able to show a cycle of irregularities. In 1685 he became assistant secretary to the Royal Society, and retained this position until 1692. During these seven years he edited the "Philosophical Transactions" of the society, and contributed papers dealing with a wide range of scientific subjects.

Perhaps the greatest, and certainly one of the most admirable, of all Halley's gifts to science was, paradoxically, the gift of Newton's "*Principia*". It is very doubtful whether, without him, this work would ever have been given to the public, for Newton himself was exceedingly diffident respecting his productions. It was Halley who presented to the Royal Society an account of Newton's work, and he was deputed by the society to "jog Newton's memory" to keep his promise of producing the book for publication; and, finally, it was from Halley's pocket that the expenses of bringing it out were defrayed. As Dr. James Glaisher said: "He paid all the expenses, he corrected the proofs, he laid aside all his own work in order to press forward to the utmost the printing. All his letters show the most intense devotion to the work."

In 1698 Halley had become greatly interested in the variations of the compass, and he obtained from William III the command of a war sloop, in which he cruised until 1700, and in 1701 published

the results of his investigations in a "General Chart" showing these variations at a glance.

In 1701 he cruised in the English Channel, making a survey of the tides and the coasts. Then followed, in 1702, an exploration of the harbors of the Adriatic. He had the use of the same ship on each occasion, the *Paramour Pink*.

In 1703 Halley was appointed Savilian professor of geometry at Oxford, a position which had been refused to him in 1691, on account of supposed atheism. He now published editions of Apollonius and other ancient writers, and edited a repudiated edition of Flamsteed's "*Historia Cælestis*".

In 1705 Halley presented to the Royal Society a paper containing his famous prediction of the return of the Great Comet of 1682 in a period of about seventy-six years. He had succeeded in identifying it with the comets of 1531, 1607 and 1682. This prediction was duly fulfilled in the return of "Halley's Comet" in 1758.

In 1721 Halley was made Astronomer Royal, on the death of Flamsteed. Although then sixty-four years of age, he at once entered on a minute study of the moon's motion, which extended over a period of sixteen years. This work was valuable, but it has been suggested that so absorbed a devotion to observation of this particular kind is hardly consonant with the duties of an Astronomer Royal. However that may be, it is certain that Bradley, on his accession to the office, found the instrumental department of the Royal Observatory in hopeless confusion. The lunar tables embodying the results of this protracted study were published in 1749, after Halley's death. Other subjects of his investigations were connected with the orbits of Jupiter and Saturn, the proper motion of the stars, the acceleration of the mean motion of the moon, and his prediction of the circumstances of the total eclipse of the sun which took place on May 2, 1715. In the same year there was a splendid display of the great aurora, of which Halley took careful observations.

In 1729 Halley was elected a member of the French Academy of Sciences. He died at Greenwich on January 14, 1742.

SIR JOHN HERSCHEL
A Tireless Sweeper of the Heavens

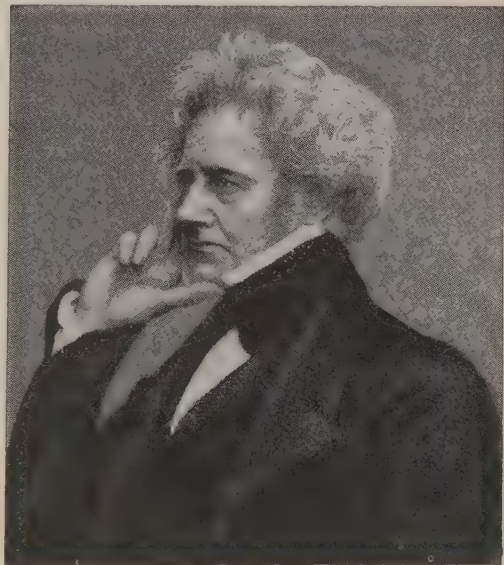
JOHN FREDERICK WILLIAM HERSCHEL was born at Slough, in England, "under the shadow of the great telescope", on March 7, 1792. He was the only child of Sir William Herschel, and this fact may be said to have shaped his life. Astronomy was not a natural bent with him, but he was born into an astronomical inheritance. His pursuit of this science was a realized devotion to his father. He was educated at home by a tutor until he went to Cambridge, where he entered St. John's College in 1809, and in 1813 was graduated with high honors and made a fellow of his college.

He continued to pursue the study of pure mathematics so far as to contribute several brilliant papers on mathematical subjects to the Royal Society, for which he received the Copley medal in 1821.

Sir William wished his son to enter the Church, but the lad had no inclination for it, and in 1814 was enrolled as a student at Lincoln's Inn. But science soon reclaimed him from the study of law. Physics, and especially the science of light, had at all times a powerful attraction for him. "Light," he said in later years, "was my first love," and from time to time he wrote papers of great value upon this subject. In September, 1816, Herschel finally joined his father in his astronomical work at Slough, and set about the task of revising Sir William's catalogue of double stars. From 1821 to 1823 this work was carried on with Sir James South at Southwark, and the results obtained for the authors the Lalande prize of the French Academy and the gold medal of the Astronomical Society.

On the death of his father, in 1822, Herschel took upon himself as a sacred charge the special objects of Sir William's studies and observations. The double stars, the nebulae, the "sweeping" of the heavens, were for him a labor of love. In 1825 he set to work on a review of the 2500 nebulae of Sir William Herschel's catalogues, and pursued his task with so much energy that it was completed in

about half the time that it was expected to take, and the results were presented to the Royal Society in 1833. This memoir was of immense importance, not only because Herschel possessed at that time the only instrument capable of showing many of these objects, and his observations included over five hundred nebulae which had never been seen before, but also because it contained much profound speculation upon the nature and relations of nebulae. It was illustrated by many careful drawings. While working at the nebulae, Herschel had also discovered over three thousand double stars, but many of these would now be rejected as too far apart to be true binaries.



SIR JOHN HERSCHEL

Having verified and supplemented his father's observations of double stars and nebulae, Herschel took his instruments and family to the Cape, in 1833, in order that he might extend the "sweepings" of the heavens to the southern hemisphere. For four years he remained at Feldhausen, six miles from Cape Town, in a most beautiful and advantageous position. It was the happiest time of his life. His whole heart was in the work and he accomplished an almost incredible amount. The survey of the southern heavens was completed, and many special detailed observations of great value were made.

During this time Herschel observed 1202 double stars and 1708 nebulae, most of them being new discoveries: the Magellanic Clouds, the Milky Way, Halley's Comet, sun-spots and other celestial phenomena. In every case he added not only invaluable stores of observation, but also very enlightening discussions. His catalogue of nearly five hundred stars in order of brightness, according to the "method of sequences" suggested by his father, linked together stars of the northern and southern hemispheres in a single chain, and introduced a definite ratio of magnitude.

In 1838 Sir John Herschel finally returned to England, where many honors were showered upon him, but he never again took up observational work; he set himself instead to the task of arranging and publishing the materials already collected. The results of the Cape visit were published in 1847, the "General Catalogue of Nebulae" in 1864, a monumental work which still retains authority as a standard guide, and in 1867 a general list of double stars. He did not live to give to the latter the comprehensive and descriptive character which he had desired. He died at Collingwood on May 11, 1871, and was buried near Newton in Westminster Abbey. Honors of every kind had been heaped upon him. He was elected a member of many great foreign learned societies, and was created a baronet at Queen Victoria's coronation.

Sir John Herschel's services to science were by no means limited to his astronomical observations and deductions, valuable though these are. His studies in optics led the way to great advances in photographic processes and in spectroscopy. He was the first to use sensitized glass plates, and the first to attempt spectral photography. As early as 1827 he ardently supported the undulatory theory of light put forward by Young and Fresnel, and secured for it general acceptance by an article in the "Encyclopædia Metropolitana". We have already referred to his work in pure mathematics. His "Outlines of Astronomy", a book at once popular and of scientific value, was published in 1849, and has been widely translated.

SIR WILLIAM HERSCHEL The Breaker of the Barriers of the Sky

SIR WILLIAM HERSCHEL was born in Hanover, Germany, on November 15, 1738, the fourth of ten children of Isaac Herschel, an oboist in the band of the Hanoverian Guard. After a short course at the garrison school, he entered the band at the age of fourteen. At the beginning of the Seven Years' War his parents, finding that the campaign was breaking down his health, smuggled him away to England. For this act of desertion Herschel received a written pardon from George III in 1782.

In 1757 Herschel landed in England, with a French crown-piece and his musical talent as sole means of support. He earned his living as a music teacher in various towns, began gradually to be known, and in 1766 became a member of the Pump Room orchestra at Bath. The next year he was appointed organist to the new Octagon Chapel, and in 1776 succeeded Lindley as concert director in Bath. By this time he was well on his way to fame and fortune as a musician. In 1771 he had sent for his brother Alexander, and in 1772 for his favorite sister, Caroline, to take part in the concerts.

But music was not by any means sufficient for William Herschel. He had an insatiable desire for knowledge, and the reading of Ferguson's "Astronomy" impelled him to seek for himself the wonders of which it spoke. He could not afford a good telescope, but this did not check his ardor. He determined not only to make his own instrument, but to make one more powerful than any which had yet existed. The house was thrown into utter confusion while the brothers and sister, with the help of a carpenter, set to work with the zest of children. After no fewer than two hundred failures a reflecting telescope was successfully constructed five and a half feet in focal length, and of five-inch aperture. From this time Herschel labored unintermittingly to produce a telescope of the highest possible magnifying power. The two hundred failures had given him a mastery in

the art of making specula, or telescopic mirrors, in which art he has probably never been equaled. But there have been few with an ardor such as his, which on one occasion never left off polishing a speculum for sixteen hours, lest the removal of his hand should impair its surface.

Herschel's lifelong passion was to "review the heavens", in the profound sense; to know the celestial bodies, as far as possible, as they really are; to arrive at some conception founded on reality as to the construction of the starry universe. This was the source of his devotion to the perfecting of his instruments, and of the at-

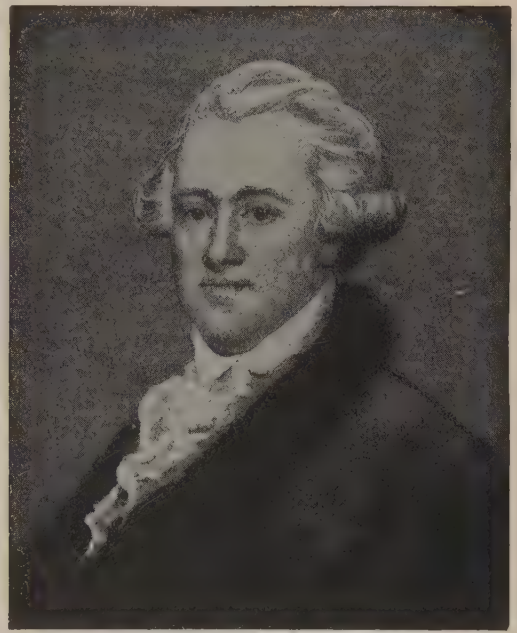
several failures, a magnificent twenty-foot reflector with a twelve-inch mirror was set up in 1781; yet even this did not satisfy Herschel, and he set to work to construct a thirty-foot instrument. Meanwhile, a fortunate incident had decided his career, and relieved him from the strain of his double profession. This was his discovery, on March 13, 1781, of the planet Uranus — a discovery unprecedented in the records of astronomy. Herschel at once became famous. He was appointed in 1782 Astronomer Royal, at a salary of £200, and from this time devoted himself to astronomy alone.



CAROLINE HERSCHEL

tention he always gave to the highest possible development of his own powers of vision. This fervent love of reality led him, with the instinct of genius, from one discovery to another, so that at eighty-three he was still inspired with the same quest, though at last unable to pursue it.

The making of telescopes went on steadily in every interval of Herschel's numerous musical engagements, and every clear night found him at his telescope surveying the heavens. In 1775 he constructed a seven-foot instrument which already surpassed any existing telescope in the distinctness of its images. After



SIR WILLIAM HERSCHEL

By the sale of his telescopes, Herschel procured the funds necessary for his projected giant forty-foot telescope. His instruments went all over Europe, and for several he received sums of \$10,000 or \$15,000 each. But he was fortunately relieved from the necessity of laboring as a mere mechanician by royal grants. The forty-foot instrument, begun in 1785, was set up four years later. Its first use disclosed a new Saturnian satellite, Enceladus; and three weeks later the seventh satellite, Mimas, an object which is not discernible by any except the very highest telescopic power.

The giant reflector was, however, too unwieldy for constant use, and was only employed for special observations. It was with the twenty-foot that Herschel chiefly carried out his projected sweeping of the heavens. This task may be said to have been at once his supreme passion and his life work. It yielded an incomparably rich harvest of particular discoveries, and of scientific conclusions. But the ultimate value of Herschel's labors lay not so much in his many discoveries, nor in the inferences and conjectures which his genius so often drew unerringly from observation, as in the ardor and power which led astronomy, from mere theorizing, back to the heavens themselves. At the time when he began his explorations, astronomers were absorbed in attempts to prove or disprove Newton's generalization, and observed the heavens simply to that end. The stars were receiving almost no study for themselves. Telescopes had never been constructed with any definite idea of securing true and clear images of celestial objects. Sidereal physics and sidereal construction had hardly been conceived of as subjects for practical investigation. But since Herschel led the way the progress of discovery in these directions has been very rapid.

Herschel's own contributions to astronomical knowledge and theory were, however, very considerable. The study of double stars and of nebulae was first seriously undertaken by him; and even after his death his son possessed the only instrument capable of showing many of the nebulae which he had discovered. In his "sweeping" observations, which he completed over the whole northern sky, he gathered in a multitude of previously unknown double stars; a catalogue of 269 of these was presented to the Royal Society in 1782, and a second list of 434 in 1784, the large majority being new discoveries. Herschel was the first to perceive the color harmonies in some of these binaries. His discoveries of nebulae, of their disposal in space and of their relations with stars are perhaps even more important. From his early view of nebulae as separate "universes" consisting

of innumerable stars, he was led by his observations to the conclusion that there exists in space a "shining fluid", of which many of these objects are composed. His studies of the sun were very thorough and diligent; he traced out the whole course through which individual sun-spots run, and endeavored to establish some relation between sun-spot variations and changes on the earth. He discovered two new Saturnian and two new Jovian satellites, set on foot the modern study of the physical features of Mars, originated the "trade-wind" theory of the belts of Jupiter, and fixed the period of Saturn's rotation. He also instituted a new system of stellar classification in a regular sequence of magnitudes, a method which has been valuable especially in relation to the study of light variation.

Herschel married, in 1788, Mary, widow of John Pitt. They had one child, John, who rivaled his father's fame as an astronomical observer. Herschel was knighted in 1816, and in 1821 was elected first president of the Royal Astronomical Society. He died at Slough on August 25, 1822. Above his grave are the words: "*Caelorum perrupit claustra*" (he broke through the barriers of the skies).

CAROLINE HERSCHEL A Great Man's Great Sister

CAROLINE HERSCHEL was eleven years younger than her "dearest and best" brother William, having been born at Hanover on March 16, 1750.

As soon as William was earning a sufficient income in Bath, he sent for Caroline to join him, in 1772. She became a singer when he was concert director, an untiring assistant when he became an explorer of the heavens. Caroline was at first by no means pleased at the change; the road to success was well open before them in a musical career, but there was nothing to be seen of great promise from the heavens. But her devotion to her brother stifled the revolt of her practical common sense, and nothing could exceed the completeness of that devotion, which was entirely without consciousness of self. Throughout the long hours of the night-watches she

was always at her post, recording, assisting in mechanical operations, entering into all that was going on. Without her aid, William Herschel could never have got through anything like the amount of observation which he accomplished.

Although nothing was ever allowed to interrupt for a moment her services as her brother's assistant, Caroline Herschel found time during his absences to sweep the heavens on her own account and became famous as the discoverer of eight comets. She was a favorite with the Royal princesses, and received attentions from many persons of importance, but all these things left her unspoiled. Her whole life had but a single purpose—to serve; and her strong heart a single devotion—her brother. Although she lived for nearly twenty-four years after his death, her life, in many senses, ceased with his. She retired to Germany and lived, honored but weary at heart, until January 9, 1848, when she died at the age of almost ninety-eight. Her reduction of her brother's catalogue of nebulae and clusters was an invaluable work, to which she devoted immense labor and patience, and for this she received the gold medal of the Royal Astronomical Society.

HIPPARCHUS

The Greatest of Ancient Astronomers

ABOUT the middle of the third century B.C., a spirit of realism entered into Greek thought, and one of the results was that astronomy began to be treated as a science. That is to say, philosophers were no longer satisfied merely to produce fanciful theories of the universe based upon conjecture rather than upon fact. Observation and calculation became predominant, and hypotheses were relegated to their rightly subordinate place. The systems of Eudoxus and of Aristarchus alike broke down under the test of more careful and detailed observation of the planetary motions. It is the great merit of Hipparchus, the famous predecessor of Ptolemy, that he was more interested to investigate the actual motions and irregularities of the planets than to build up an elaborate theory of the universe.

Hipparchus was born at Nicæa, in Bithynia, nearly at the beginning of the second century before our era. Nothing is known of his personal history. The earliest recorded date of his observations is 161 B.C., and his only book which has come down to us bears the date of 140 B.C. A large part of his life was spent at Rhodes, which was a center of great intellectual activity. Here he made his observations and, in 130, the capital discovery of the precession of the equinoxes. The outburst of a new star in 134 is stated by Pliny to have suggested the preparation of his catalogue of 1080 stars divided into six classes of magnitude, which is one of the finest monuments of ancient astronomy, and substantially embodied in Ptolemy's "*Almagest*". Hipparchus founded trigonometry and compiled the first table of chords. This is known to us through the works of Theon of Alexandria. Scientific geography originated with his invention of the method of fixing terrestrial positions by circles of latitude and longitude. He was the inventor of the astrolabe. Only one of his many works has survived, a commentary on the *Phænomena* of Aratus and Eudoxus. There can be little doubt that the fundamental part of his astronomical knowledge was derived from Chaldea, but his borrowings were doubtless independently verified. It is probable, too, that he is the Hipparchus who wrote on combinatory analysis, and that the Arabs were correct in attributing to him a knowledge of the quadratic equation.

The system of Hipparchus, which was adopted and elaborated by Ptolemy, was in many points erroneous. None the less, it marked an immense advance, inasmuch as it was really a serious attempt to describe in reasoned form the actually observed motions of the planets. It contains, therefore, a substratum of truth, and has been of inestimable value as a foundation of astronomical science. Hipparchus worked out his system most fully in relation to the sun, and showed that the supposed movements of that body could be accounted for either on the theory of the eccentric circle or on that of the

epicycle. This was reasonable enough, for the resultant error was too small to be appreciable with the instruments which astronomers had then at their command. Hipparchus was also the discoverer of the precession of the equinoxes — that is to say, of the fact that the nodes, or intersections, of the earth's orbit, which was then, of course, regarded as the sun's orbit, with the plane of the equator were not absolutely fixed, but had a slow backward movement.

This ancient astronomer also worked out a theory of the moon and her elusive movements, but with less success than that which attended his explanations of the sun. It is characteristic of Hipparchus that he realized the imperfections of his theory, though he confessed himself unable to remove them. In a similar way, though in a much greater degree, he was to the end dissatisfied with his knowledge of the movements of the planets — so much so that he never elaborated a planetary theory. He corrected the observations which had been made by his predecessors, and was himself a scrupulously accurate observer, but he deliberately left the interpretation of these results to future generations. In this respect, as in so many others, we can see that his views of human knowledge, and of the celestial system alike, were far more profound than those which were current in his time. Early Greek astronomers had been accustomed to found their theories upon observation of the planets at their moments of opposition only, but Hipparchus, on the contrary, recognized that the movements of these bodies must be sedulously followed throughout their entire orbits. In making thorough observations of this kind, he soon found that neither the epicycle nor the eccentric was capable of explaining planetary motion, and there he was obliged to leave the matter — to Copernicus.

In addition to his work on the solar system, Hipparchus is known to have compiled a catalogue of stars, which formed the basis of Ptolemy's later catalogue. Ptolemy, who fixes its date at 129 B.C., did very little more than edit it.

SIR WILLIAM HUGGINS

The Pioneer in the Field of Astrophysics

SIR WILLIAM HUGGINS, pioneer in the science of astrophysics, was born in London on February 7, 1824. He was educated for two years at the City of London School, and from 1839 by private tutors at home. His education was of the usual literary kind, but his own inclination was always towards science. His earliest fancy was the microscope, and from 1852 he was a member of the Royal Microscopic Society. While he was still a young man, after a brief commercial career, Sir William Huggins succeeded to a private fortune, and thenceforward his sole interest was astronomy. As early as 1854 we find him a member of the Astronomical Society; and by the spring of 1856 he was fully equipped with an observatory of his own, fitted with an equatorial telescope of five-inch aperture and other instruments. This observatory was built in his garden at Tulse Hill, in London, where he lived and worked until his death.

After becoming an expert in the methods of astronomical observation which were familiar at that time, Sir William was attracted, in 1862, by the idea of spectroscopy, owing to a treatise by Kirchhoff which showed how the dark lines of the solar spectrum could be made to reveal the physical conditions of the sun. Greatly interested in the new vista of knowledge thus opened up, Sir William Huggins set to work at once to apply the same method to the profoundly suggestive investigation of more distant celestial objects.

Together with Sir William Allen Miller, he adapted the spectroscope to the study of the stars; and with their new instrument they examined the physical constitution of Betelgeux and Aldebaran, and after these of Sirius. Sir William was the pioneer in this work of searching investigation of the spectra of individual stars, which has revealed entire new worlds of knowledge to the astronomer. For long he worked almost alone in this field. Donati's experiments, though earlier in date, were unsuccessful because his apparatus

was unsuitable to the work. Secchi, who was working at stellar spectroscopy at about the same time as Huggins, made no detailed examination of special stars, but swept rapidly through the heavens in search of general results and was thus the first to classify the stars according to their spectra. The careful analytic methods of Huggins, which were quite new to astronomy, resulted in establishing a general similarity, and many profoundly

trium which showed its gaseous constitution, and that it consisted largely of hydrogen, a fact which confirmed the latest belief of Sir William Herschel. The Andromeda nebula, on the contrary, gave a continuous spectrum. These discoveries were of immense importance in clearing away the difficulties in the way of the nebular hypothesis.

Several new stars now came under the test of the spectroscope in the hands of



SIR WILLIAM HUGGINS, THE VETERAN PIONEER OF SPECTROSCOPY

interesting differences, between the sun and the other stars.

The next spectroscopic discovery by Sir William Huggins was of epoch-making importance. He was examining, in August, 1864, a planetary nebula in Draco, and found that it gave a "bright-line" spectrum, thus proving its gaseous nature. Eight other nebulae which he then examined gave similar results; and in 1868 the Orion nebula was found to yield a spec-

Sir William Huggins. In 1886 he examined the "nova" in Corona Borealis, and in 1891 the brilliant new star in Auriga. He found that these sudden visitants were distinguished from ordinary stars by the presence of certain extremely significant bright lines in their spectra, showing evidence of a conflagration of hydrogen on a most stupendous scale. On this evidence he based his well-known explanation of "novæ".

He says, "The case is that of the casual near approach of two bodies previously possessing considerable velocities in space, such a near approach being far less improbable than an actual or partial collision. Enormous disturbances of a tidal nature would inevitably follow such approach, and produce sufficiently great changes of pressure in the interior of the bodies to cause tremendous eruptions from within, similar in kind to solar outbursts, but immensely greater."

The most important of all Sir William's discoveries was, however, his adoption of



LADY HUGGINS

spectroscopic methods for determining stellar motions in the line of sight. The method resulted immediately in most momentous results. Sirius first, and many other brilliant stars afterwards, were found to have extremely rapid movements either towards or away from the earth. Many years will pass before the uses of this method have been exhausted.

Sir William was also a pioneer in the photography of stellar spectra. After several vain attempts, he succeeded, in 1879, in obtaining photographs of several of these; and in 1882 photographed the solar coronal rays.

By all these indefatigable researches, Sir William Huggins ranks among the great astronomers; and he was undoubtedly the founder of the modern science of astrophysics. He was honored with all kinds of distinctions at home and abroad. In 1900 he was president of the Royal Society, and for many years president of the Astronomical Society. He was one of twelve chosen as the first members of the Order of Merit in 1902. He died in London on March 12, 1910.

In 1875 Sir William Huggins married Margaret Murray, who was already a keen student of the heavens; she became his sole assistant, and all his papers after their marriage were signed by both. In 1901 Lady Huggins was elected honorary member of the Royal Astronomical Society.

CHRISTIAN HUYGENS

A Great Astronomer Who Made Clocks and Telescopes

AFTER the death of Galileo and of Kepler, and before Sir Isaac Newton rose to fame, there is an interval during which Huygens stands out as by far the greatest astronomer of his day. Born at the Hague on April 14, 1629, Christian Huygens de Zuylichem belonged to a wealthy and distinguished family. His father was secretary and adviser to three successive princes of Orange, and his elder brother, Constantine, succeeded to this responsible office and went to England in 1688 with William of Orange.

Christian showed early signs of a very remarkable mind and his father, as was usual in those days, educated him as rapidly and widely as possible. He was instructed in music as well as in the literary subjects which were customary at the period, and at the age of thirteen he was introduced to the construction of machines, an occupation for which he gave evidence of extraordinary ability. At sixteen years he was sent to Leyden to study law, and twelve months later to the University of Breda, where he plunged into mathematics, which always remained his favorite study. His first mathematical essays brought him to the notice of Descartes.

On leaving the university, in 1649, he traveled with the Count of Nassau, and on his return to Holland set to work with enthusiasm on the most abstruse mathematical problems and on the mechanical inventions which are his chief title to fame. He published treatises on the quantities of the parabola and other geometrical figures, and at the same time began to grind and polish lenses for large telescopes, becoming the maker of instruments superior to any which existed at the time. It was with a twelve-foot telescope of his own handiwork that he not only discovered, in 1656, a sixth satellite of Saturn, Titan, but determined the period of its revolution.

Huygens was the first to apply the pendulum to clocks, and to employ the device to determine the acceleration of gravity.

It would be impossible even to enumerate the many astronomical discoveries which Huygens initiated, but certainly his most illustrious observations were those by which he first understood the nature of Saturn's rings. That planet had been a most baffling puzzle to astronomers ever since the telescope had revealed its apparently triple form, for Saturn changes remarkably in appearance according as the rings are viewed edgewise — when they disappear, except to the most powerful telescopes — or are seen more or less in face. Having by far the best optical instrument of his age, Huygens was able, in 1656, to announce the true relation of Saturn and its rings, though he was not able to separate the ring-system into its component members. In "The System of Saturn", wherein the whole matter, so far as at that time disclosed, was clearly set forth, he records other important astronomical observations. For example, he describes the bands on Jupiter, the principal markings of Mars and the Orion nebula. He was able also to define the very significant fact that, even in the largest telescopes, the stars, as distinguished from planets, have no diameter, but are mere points of light without dimensions.

From this discovery he very naturally turned to the determination of the diam-

eters of the several planets, and invented an instrument for the purpose. This, as modified later, became the micrometer which is used in modern observatories. It should be said, however, that a previous worker in the same field, Gascoigne, who was killed at the battle of Marston Moor in 1644, had constructed a true filar micrometer, but the invention remained unknown for many years afterward.

Huygens visited England in 1660, and was admitted a member of the Royal Society. It was a time of general scientific revival, and the French Academy of Sciences, which was being founded about the same time, persuaded Huygens to take part in its direction, offering him at the same time princely remuneration. He acceded to their request, and remained in Paris until the year 1681, when he resigned his position on account of failing health, and returned to his native Netherlands.

To a man of this type, Sir Isaac Newton's "*Principia*", which he secured in 1689, was a revelation and a delight. His first impulse was to cross the Channel once more, and get to know the author and, having done so, he wrote and published two important works, under the influence of Newton, on light and on weight respectively. But he was now coming near to the end of his days. His last illness began early in 1695, and he died on July 8 of the same year.

The work he did was much more copious than can be even suggested by this brief notice. He did important work in optics and he is regarded as the founder of the waves theory of light. He had few equals in higher mathematics, and Newton praised his style and methods of mathematical exposition, and paid him the compliment of confessed imitation. He was a great expounder of the differential calculus, initiated by Pascal but still at this time generally unknown. Another important work dealt with the movements resulting from percussion, being an inquiry closely related to the modern science of ballistics. A lighter and more fanciful late work, entitled "*Cosmotheoros*", consists of conjectures on the physical constitution of distant worlds and their inhabitants.



JEREMIAH HORROCKS FIRST OBSERVING THE TRANSIT OF VENUS BY CAUSING THE SUN'S DISC TO BE THROWN THROUGH A TUBE INTO A DARK ROOM, SO AS TO SHOW THE PLANET CROSSING THE SUN'S FACE, AS HE HAD FORETOLD. FROM THE PAINTING BY EYRE CROWE IN THE WALKER ART GALLERY

THE OUTERMOST PLANETS

The Plumbing of the Depths of Space to Find
Slow-Moving Uranus and Neptune the Invisible

PROBLEMS OF THE PLANETARY SYSTEM

LEAVING behind us Saturn and his gorgeous retinue of rings and satellites, we must now proceed to the outer confines of the planetary system. Two planets circulating at vast distances from the sun, Uranus and Neptune, remain to be considered; and before leaving the subject of the planets we shall review certain general questions of their origin and history.

Saturn was the last of the planets known to the ancient world; we have precise observations of its position and movements from as far back as the third century before Christ; and as a star of the first magnitude it must have been well known from the earliest times when men began to observe the sky. From that remote period until near the end of the eighteenth century, no new planet was discovered, although Uranus was all the time quite visible to clear eyesight. But, slowly as Saturn moves among the stars, Uranus moves far more slowly, taking over 84 years to complete a single circuit of the sun. There was therefore no possibility that the wanderings of this distant world should be noticed, and its planetary nature discovered, until the science of astronomy was far advanced and had become highly organized. Neptune, which so far as is known at present, is the outermost planet of our system, is quite invisible to the unaided eye, and could never have been discovered except for the union of finely constructed astronomical instruments with the highest powers of mathematical reasoning. Uranus was found by accident, but the existence and position of Neptune were predicted, by exact calculations, before the planet had ever been seen.

Sir William Herschel, the eminent German-English astronomer, never satisfied with the performances of his instruments, made with his own hands one after another of ever-increasing size and power, until he finally had a better telescope than any other then existing. It was on March 13, 1781, that he discovered Uranus, which he took at first to be a comet. He was searching through the constellation of Gemini when he came upon a star which appeared to show a disc, being thus distinguished from fixed stars, which remain mere points of light even under the highest powers of the telescope. He found that this star could just be seen without a telescope, being of the brightness known as the sixth magnitude. Turning a higher power upon it, he noticed that its disc was enlarged in proportion. There was then no question that he had come upon some celestial body other than a fixed star.

Observing it on successive nights, he perceived that it changed its position among the stars. Still, however, it never occurred to him that this might be a planet. The number of the planets had been known from antiquity, and telescopes had been freely used for over a century and a half without the discovery of a new one. It was natural that Herschel should come to the conclusion that his moving star was a comet; and it was under that title that he published his account of its discovery.

The supposed comet was carefully followed at the principal observatories of Europe, and was found to move far otherwise than a comet might be expected to do. Instead of pursuing an extremely eccentric elliptical path, so as to pass comparatively near the sun, and then to plunge into re-

mote distances of space, the new star gradually revealed an apparently circular orbit, situated far outside the orbit of Saturn. As the months went on, this circular orbit became more certain, and Sir William was soon acclaimed as the discoverer of a new planet which he named *Georgium Sidus* ("George Star", after his royal patron George III of England) but which others, for some years, called after its discoverer "Herschel".

The improved namings of the planet which Herschel found

But the name Uranus, which was proposed by the German astronomer Bode soon after its discovery, received at last the sanction of the scientific world, as more in accordance with the method in which the other planets had been named. In ancient mythology Uranus was father of Saturn and grandfather of Jupiter. After the planet's orbit had been fully calculated, it was found that Uranus had been seen many times before, and noted down on star-maps as a fixed star.

The mean distance of Jupiter from the sun is 483,000,000 miles, that of Saturn 886,000,000 miles; and that of Uranus nearly 1,800,000,000 miles, or twice the distance of Saturn. The orbit of Uranus is fairly eccentric, so that the planet is 166,000,000 miles nearer to the sun at perihelion than it is at aphelion. It was last at perihelion—that is to say, the point in its orbit which is nearest to the sun—in 1883, and will return to the same position in 1967. The orbit is inclined to the plane of the ecliptic by less than one degree. Uranus moves in its orbit at a speed of about $4\frac{1}{3}$ miles in a second, and performs a complete circuit of the sun in 84 years and 8 days. The earth passes between Uranus and the sun once in every 369 days and 9 hours.

Doubts that come with extreme distances in space

The great distance of this planet from our earth makes measurements of it very doubtful, but its disc has a diameter of about four seconds, which would give it a real diameter of about 32,000 miles, or

four times the earth's diameter. Its volume is about sixty-four times that of the earth; but as the density of Uranus is exceedingly low, being only slightly more than that of water, its mass is only about fifteen times that of the earth.

The remarkable lightness of the materials of which Uranus is composed shows that this planet, like Jupiter and Saturn, is mainly in the vaporous condition. Its polar flattening, due to the centrifugal force developed by its rotation on its own axis, is such that the equatorial diameter exceeds the polar diameter by about one in twelve, a degree of compression which makes the globe obviously elliptical to the eye. The speed of its rotation has not been observed with any certainty, but its period is probably about ten hours. Uranus is tilted over in an excessive degree, though quite how much is still open to question.

Being more than nineteen times the distance of our earth from the sun, Uranus receives only one-368th part of the light and heat which we receive. It is, however, a good reflector, owing to the fact that its visible surface consists of cloud. It has a very characteristic sea-green color, due to the absorption of the red and orange components of sunlight by its enormously deep atmosphere, which extends far outside the visible surface of cloud.

The moons of Uranus and the peculiarity of their orbits

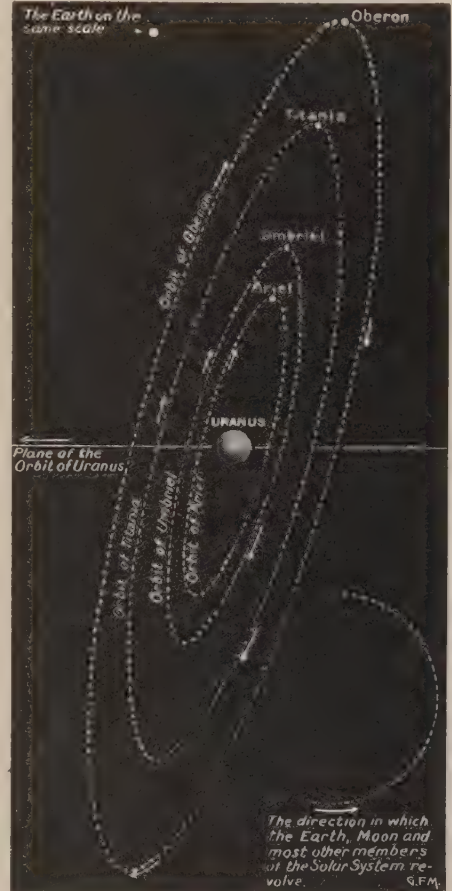
Uranus has four moons, of which the two inner, Ariel and Umbriel, were discovered by Lassell in 1851, and the two outer, Titania and Oberon, by Sir William Herschel in 1787. The orbits of these four moons are circular, and lie very close together. The remarkable peculiarity of the satellites of Uranus is that the plane of their orbits, instead of lying more or less in the plane of the planet's orbit, is almost vertical to that plane. The plane in which these satellites revolve is consequently seen from the earth sometimes edgewise and sometimes in full face. The plane of the orbits is tilted up very nearly 98° so that it is a little past the vertical, and consequently the moons revolve in the retrograde direction.

The discovery of the planet Neptune in 1846, by purely mathematical reasoning based on the movements of Uranus, as explained and illustrated on page 728, was perhaps the most astonishing feat in the history of astronomy. The difficulties and limitations of the observer are in no other science so great. He is situated millions of miles away from the objects of his investigation; and keen eyes, an alert mind and a few instruments, which are after all very simple, are all that he has to work with. The tireless enthusiasm and ingenuity which are able under these limitations to discover in the heavens an object which has not been seen at all, and to locate very nearly its exact position, are human achievements in harmony with the majesty of the planets themselves.

Part of the laborious routine of astronomy is the calculation beforehand of the positions which the several planets will occupy at definite dates and hours in succeeding months and years. Tables of these predicted planetary positions are published; and observers who are making nightly study of the sky become very soon aware of any discrepancy which may exist between these celestial time-tables and the actual position of any planet. So exact are the methods of calculation, and so regular are the planetary movements, that a discrepancy of this kind at once suggests some unknown cause which has not been allowed for in the calculation. So it was that the French astronomer Alexis Bouvard, who was at work in 1820 upon the time-tables of Jupiter, Saturn and Uranus, finding that the two former kept to their predicted positions, but that Uranus departed from its by a very minute yet measurable distance, pronounced his opinion that the planet which then formed the limit of our system was disturbed in its orbit by the attraction of another planet yet more remote. Year after year the discrepancy increased. From a distance of 20 seconds of arc in 1830, it became 90 seconds in 1840, and 128 seconds in 1846.

The perturbations of Uranus in its orbit became the absorbing question of the entire astronomical world.

This was the opportunity of Leverrier, a French mathematician and astronomer, and also of John Couch Adams, in later life professor of astronomy at Cambridge. The two attacked the problem and solved it simultaneously, though Leverrier's solution, which was announced first was the more accurate. It was in October, 1845, that Adams approached Sir



URANUS AND ITS SATELLITES

The orbits of the satellites are nearly circular, but they are shown here almost edgewise to indicate the tilt. This diagram shows the size of Uranus as compared with the relative distances of each satellite from it, and also the tilt of the whole system.

George Airy, Astronomer Royal at Greenwich Observatory, with his calculations of the position of the new planet, but it was not until July of the following year that Professor Challis, of Cambridge, began the search for it at Airy's request. Meanwhile, in June, Leverrier's calculations were published. In September, 1846, Sir

John Herschel, addressing the British Association, announced the prospect that another planet was on the eve of discovery. "We see it," he said, "as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis, with a certainty hardly inferior to ocular demonstration."

In the same month Leverrier wrote to Dr. Johann Gottfried Galle, of the Berlin Observatory, asking him to search for the new planet; and on the night of September 23 on which date he received the letter, Neptune was found within one degree of the position Leverrier had predicted.

A planet that was seen, yet not discovered as a planet

On October 3, Sir John Herschel published a statement of the calculations which Adams had made, and claimed for him an equal share in the honor of the discovery. There followed a somewhat unworthy controversy between the partisans of the two astronomers, but it is now generally admitted that they were equally deserving. As in the case of Uranus, it has since been ascertained that Neptune had been seen several times, and its position noted, before the discovery that it was a planet.

Neptune pursues a vast orbit, having a mean distance from the sun of 2,800,000,000 miles. This orbit, which is very slightly eccentric, is inclined to the plane of the ecliptic by less than two degrees. The planet moves at a speed of about $3\frac{1}{3}$ miles a second, and takes 165 years to complete its circuit of the sun. Its apparent diameter is about $2\frac{1}{2}$ seconds, and its real diameter about 33,000 miles. Its volume is about 78 times that of the earth, but its mass exceeds the mass of the earth by only about 17 times. That is to say, like the other major planets, it has very low density, and hence the greater part of its mass must be in the vaporous state. Like Uranus, which it resembles in several respects, Neptune shows a blue-green disc, invisible to the unaided eye, but plain enough through an ordinary field-glass. It is ranked according to its brilliancy as a star of the ninth magnitude.

Why the earth cannot be seen from Neptune though we see Neptune

As a reflector, it is inferior to Jupiter, Saturn and probably also to Uranus. Owing to its great remoteness from the center of our system, the sun would appear to Neptune no larger than Venus appears to us; and this distant planet receives only one-hundredth part of the light and heat which we receive from the sun. From the surface of Neptune it would be impossible to see any of the planets within the orbit of Jupiter, and Jupiter itself would appear as a morning and evening star in close attendance on the diminished sun.

The planet has a profound atmosphere, extending far outside its visible surface of cloud, and cutting off the red and orange constituents from the sunlight which it reflects. The spectroscope shows that there are elements in the atmosphere of Neptune, as of Uranus, Saturn and Jupiter, of which the nature is as yet unknown.

Although Neptune revolves round the sun in the direction in which the other planets proceed, its rotation about its own axis is believed to be retrograde; and the plane of its equator is inclined by about 35° to the plane of its orbit. There are no clear markings on the surface of Neptune. The planet has only one satellite; or perhaps we should rather say that only one has as yet been discovered. This was first seen by Lassell on October 10, 1846, eighteen days after the discovery of Neptune. It is of about the size of our moon; and its revolution round the planet is in the retrograde direction. From a discussion of 1500 observations made between 1864 and 1908, Arthur Newton of the American Nautical Almanac Office has found that the satellite revolves in a plane inclined by 14.7° to the plane of Neptune's equator. Distant by about 223,000 miles from its planet, it makes a complete revolution in somewhat less than 6 days.

Why it is unlikely that any more planets will be found

No quite certain answer can be given to the question whether there is any planet outside the orbit of Neptune. But most

probably the answer will turn out to be in the negative. Neptune does not, so far, appear to be disturbed to an appreciable degree in its orbit by the influence of any more remote body. On the other hand, it must be remembered that Neptune has not nearly performed the circuit of the sun since the year 1846. Not until the year 2010 will this distant planet have completed its prodigious circle. It has not yet been observed throughout half its course. It may yet approach and be influenced by some yet more slowly moving planet, of whose existence astronomy will then, for the first time, become aware. But any discovery of that kind becomes ever more unlikely. The sky has been searched, and the stars mapped and catalogued, with greatly increased minuteness and accuracy, since the middle of the nineteenth century. Moreover, within recent years photography has given its powerful aid, revealing hundreds of asteroids about the plane of the ecliptic, yet until now showing no planet more remote than Neptune. And finally, many have considered, not without reason, that the complete breaking down of Bode's Law, in the distance of Neptune from the sun, may be taken as showing that with this planet we have reached the outermost confines of the solar system.

Certain general conclusions which have resulted from the study of the planets may here be noticed. In the first place, the materials of which the outer planets are composed appear to be, on the whole lighter than those which enter into the composition of Mercury, Venus, the earth and Mars. This fact and its significance have already been referred to in an earlier chapter (see page 1307). It was there shown that if we take the density of water as unity, the mean density of the four inner planets is 5.1, and the mean density of the four outer planets is only 1.2. It may be mentioned incidentally that Mercury and our earth have greater density, so far as we are able to tell, than any other objects in the solar system. Now, the much greater density of the four terrestrial planets, as compared with that of the four major planets, is largely due to

the fact that the former have cooled to solidity, while the latter, on account of their great size, are still in a more or less sun-like condition — that is to say, are in all probability still vast masses of vapor, surrounded by visible surfaces of cloud.

Theories as to the cause of the differing densities of planets

But there is reason to believe that the great difference in density is also due in some degree to a difference in composition. That such a difference in composition is possible is shown by the difference in density between our moon and the earth, for the former is considerably lighter in substance than the earth, though it has certainly cooled further than our globe has done. Moreover, the vast atmospheres of Uranus and Neptune, in which free hydrogen, an extremely light gas, is known to play a large part, indicate that the lighter materials of our system may be present in larger proportion in its more distant than in its more central worlds. This is in conformity with the theory which holds that the solar system was evolved from a nebula formed by collision between two celestial bodies. In that case, the lighter substances set free would naturally coalesce in the exterior parts of the system, while the denser substances might be expected to preponderate towards the center.

In the second place, we must notice a very remarkable rhythm in the comparative dimensions of planets and of satellites, which was pointed out by Percival Lowell. "Consider first," he says, "the way in which the several planets, as respects to size, stand ordered in distance from the sun. Next to him is Mercury, the smallest of all the principal ones. Venus and the earth follow, each larger than the last; then comes Mars, of distinctly less bulk, and so to the asteroids of almost none. After this the mass rises again to its maximum in Jupiter, and then subsequently falls through Saturn to Uranus and Neptune. Here we mark a more or less regular gradation between mass and position, a curve in which there are two ups and downs, the outer swell being much the larger, though the inner, too, is sufficiently pronounced."

Signs of method in star systems that cannot be accounted for

This pattern, of an inner smaller curve, and an outer larger curve, is repeated in the system of satellites belonging to Jupiter, again in the Saturnian system and finally in the system of Uranus. "The order in which the little and the big are placed with reference to their controlling orb is the same in the solar system, and in every one of its satellite families. Method here is unmistakable." There is unquestionably some profound principle at work in this uniform arrangement, but no one has yet succeeded in even guessing its nature.

Finally, it can hardly be doubted that the retrograde movements of the outermost satellites in the systems of Jupiter and Saturn, the excessive tilt of Uranus, and the retrograde revolutions of its moons, and the same retrograde rotation of Nep-

tune and revolution of its satellite — appearing as they do only at the very periphery of the solar system, and of these subordinate systems — have some deep significance with regard to the development of the family of planets round the sun, and of moons around the planets.

A nebular hypothesis that may explain the place of the planets

Mathematical investigations have shown that for satellites beyond a certain distance from their primaries the retrograde motion is more stable than direct motion. Some authorities think that in their early stages all planets and satellites rotated in the direction we call retrograde, and that while the outermost planets and satellites have retained rotation in that direction, the axis of the others has been turned over by tidal action so as to reverse the direction of the spin.



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BEAUTIFUL FORMATION IN A COLORADO CANYON

A queer twist of the wind in Chicago Creek Canyon, Idaho Springs, Colorado, threw up a high snow-drift against a tree. Then several days of sunshine thawed the snow a little and each night there was a sharp air to freeze it all over again. The successive thaws and freezes produced this young glacier, which was doomed to death in its infancy, because in Chicago Creek Canyon the average temperature is a good deal higher than on the crest of Pikes Peak or Mount Evans.

VEGETABLES AS FOOD MATERIAL

A Safeguard to Health and a real
Necessity in a Well-Balanced Dietary

WHAT A KITCHEN GARDEN HAS TO OFFER

THE number of vegetables utilized for human consumption is exceedingly large, but a natural division into three main groups is made possible because of certain important characteristics they possess in common. This classification is as follows:

- 1. Green Vegetables — such as spinach, celery, cauliflower, string beans, etc.
- 2. Roots, Tubers and Bulbs — as the potato, carrot and onion.
- 3. Legumes — as the pea, bean and lentil.

Composition and food value

Green Vegetables have been recognized as an especially valuable asset to the diet only within the last few years. They include those which are leaves, stems, flowers or fruits of the parent plant. In order to understand something of their food value it is necessary to know the specific rôle each part plays in the life of the plant. The stem is the carrier of water and nutritive material; the leaves are to be regarded as the lungs, merely a sort of framework for the green coloring matter, chlorophyll, by which the plant breathes; the flower is the particular structure by means of which seeds are produced; the fruit is the fleshy protective covering of the seed. This group of vegetables represents those parts of plants in which water is abundant rather than those in which the plant has laid by a compact store of food material for its future use. Although these vegetables are apparently solid in character they all, with one exception, contain over 90 per cent water, whereas milk, which is a fluid, has only 87 per cent. This high water content is of value, as it helps to add the necessary bulk to the diet.

The total solids average between 6 and 8 per cent, consisting of carbohydrate from 2 to 5 per cent; protein from 1 to 2 per cent; mineral matter about 1 per cent, and a very small amount of fat.

In the following table the 100-Calorie portion has been used as the standard for comparison (see figures 1 and 2).

DISTRIBUTION OF CALORIES IN
100-CALORIE PORTIONS*

VEGETABLE	APPROXIMATE MEASURE OF 100-CALORIE PORTION	CALORIES FROM		
		Protein	Fat	Carbohydrate
Asparagus	4-5 servings	33	5	62
Cabbage	4-5 servings	20.5	8.5	71
Cauliflower	4-5 servings	23.5	15	61.5
Celery	8-10 servings	24	5	71
Lettuce	100 medium leaves	25	14	61
Spinach	4-5 servings	35	11	54
Squash	4-5 servings	12	10	78
String beans	4-5 servings	22	6.5	71.5
Tomatoes	3-4 servings ($\frac{7}{8}$ pt. or 5 small tomatoes)	21	8	71

* Calculated from tables in Bulletin 28 (revised edition) of the U. S. Department of Agriculture.

This table shows that of the vegetables mentioned, squash is the only one yielding less than 20 Calories, out of the hundred, from protein, while both spinach and asparagus yield over 30. It has been estimated that providing the daily diet supplies the calorie requirement of the body the amount of protein will be adequate if it furnishes from 10 to 15 per cent of the total calories. It is evident that green vegetables contain a proportionately large amount of this particular constituent. A study of the size of the 100-Calorie portion

in each case will show, however, that it is impossible to obtain a large amount of protein from the ordinary serving. For example, whereas the 100-Calorie portion of spinach yields as much as thirty-five calories from protein, yet one serving of this vegetable would give only about seven. It is for this reason, then, that green vegetables are regarded as poor sources of protein, though certainly not devoid of it.

The amount of mineral matter which these vegetables contain is relatively large and confers upon them much of the value they possess as foods.

MINERAL CONTENT IN 100-CALORIE PORTIONS

VEGETABLE	IN 100-CALORIE PORTION, WEIGHT OF		
	Calcium, gms.	Phosphorus, gms.	Iron, gms.
Asparagus . .	0.122	0.177	4.51
Cabbage . . .	0.143	0.092	3.49
Cauliflower . .	0.403	0.200	1.97
Celery . . .	0.421	0.201	2.70
Lettuce . . .	0.224	0.224	7.85
Spinach . . .	0.281	0.285	15.06
Squash (winter)	0.040	0.061	1.30
String beans .	0.110	0.126	2.65
Tomatoes . .	0.050	0.113	1.75

From H. C. Sherman's "Chemistry of Food and Nutrition" (revised edition).

Consider the iron content first. Investigations indicate that the day's requirement averages about fifteen milligrams. From the table it is seen that spinach contains fifteen milligrams in a 100-Calorie portion, lettuce about one-half this amount and asparagus almost one-third. Here again, because of the size of the 100-Calorie portion, it is evident that although this amount of iron is not available, at least one-fifth of the daily iron requirement would be obtained from an average serving of spinach (a 20-Calorie portion). This particular mineral constituent seems to be closely associated with the green coloring matter of the plant. It is found more abundantly in leaves, such as spinach and lettuce, than in stems — as celery. The chief value of this vegetable iron is that it is in the organic form which is most easily assimilated. From

the table it may also be noted that green vegetables are very good sources of both calcium and phosphorus as well as iron. The richness of this group in the essential minerals is of great importance.

Green vegetables are also of great value from the standpoint of vitamins. It is only within the last few years that any definite information has been obtained regarding their vitamin content. Leaves of plants have been found to contain an abundant supply of vitamin A. In this respect spinach ranks very high. It has been found by certain investigators that when rats were fed on a diet containing 5 per cent of spinach, as the sole source of this vitamin, long continued growth was maintained. With cabbage more than 15 per cent was necessary to secure the same result. Dried tomato was found to promote growth just as satisfactorily as an equal weight of butter fat, which is one of the most important sources of vitamin A. Our present knowledge indicates that one of the chief characteristics of this vitamin in plant tissues is its stability on heating or drying. This is of great importance, as it means that in the cooking of these vegetables their content of vitamin A is not to any extent diminished. With few exceptions, vitamin B is found in green vegetables more abundantly than vitamin A. Spinach, cabbage and tomato are particularly rich in it. In experimenting with rats investigators have found that a diet containing 10 per cent of spinach supplied sufficient vitamin B for growth but 15 per cent of cabbage was necessary. This vitamin has been shown to be less stable to heat than vitamin A. When the food is heated to above boiling point (212° F.) deterioration of the vitamin is caused with the result that cooked food has to be supplied in larger quantities than raw. In commercial canning or other high-pressure cooking there is great danger of the partial or complete destruction of this vitamin. In the ordinary cooking of vegetables there may be little deterioration but it is possible that a large part of it passes into the vegetable water. If this is not used the vitamin may be lost to a great extent.

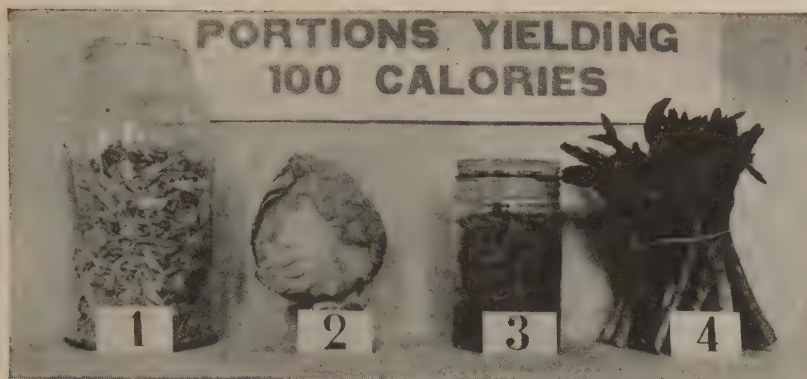


FIG. 1. 100-Calorie portions
 1. Shredded cabbage in a 2 quart sealer
 2. Cabbage
 3. String beans (cooked) in a 1 pint sealer
 4. Asparagus



FIG. 2. 100-Calorie portions
 1. Spinach
 2. Spinach (cooked) in a 1 pint sealer

Vitamin C, which has notable antiscorbutic properties, is present in large quantities in tomato and cabbage and makes them particularly good antiscorbutics. Both rank very high and compare favorably with orange juice. Cooking is found in most cases to diminish or entirely destroy the efficiency of a vegetable as an antiscorbutic. For example, cabbage cooked for one hour at 140°F. , or twenty minutes at 194°F. , lost about 70 per cent of its antiscorbutic value, and for one hour at 194°F. more than 90 per cent. Vegetables which have been cooked a long time or canned are thus of little value as antiscorbutics. There is one important exception to this, canned tomato, which has been successfully used as a substitute for the more expensive orange juice to prevent scurvy in infants receiving pasteurized milk. Drying has been found to lessen the value of an antiscorbutic food, but dried tomatoes still retain a significant amount of the original high antiscorbutic potency.

The small amount of carbohydrate (sugar and cellulose) which the green vegetables contain also adds to their value. They are usually classed as 5 per cent vegetables because the carbohydrate content is approximately that amount. In special diets where it is necessary to restrict the carbohydrate intake, such as in diabetic diets, the 5 per cent vegetables are given an important place. In planning the ordinary diet it is advisable to add some vegetable for the sake of minerals, vitamins and bulk without increasing the total fuel value to any great extent. This can be done by introducing the 5 per cent vegetables.

These vegetables are very important sources of cellulose. For example, one average serving of cabbage, of cauliflower or of spinach supplies more than twice as much cellulose as one of rolled oats. This cellulose, acting as roughage, aids in increasing the peristaltic movement in the intestine, which is so essential in maintaining health.

FIG. 3. 100-Calorie portions
1. Beets
2. Carrots
3. Carrots (cooked) in a 1 pint sealer
4. Mashed potatoes
5. Onions
6. Potato
The mug is a standard half-pint cup

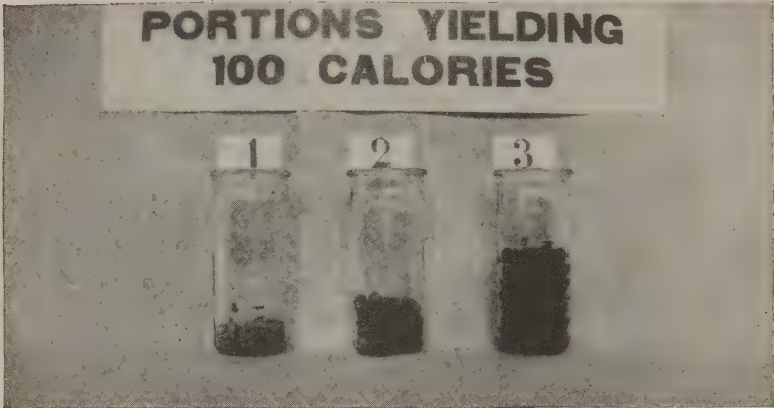
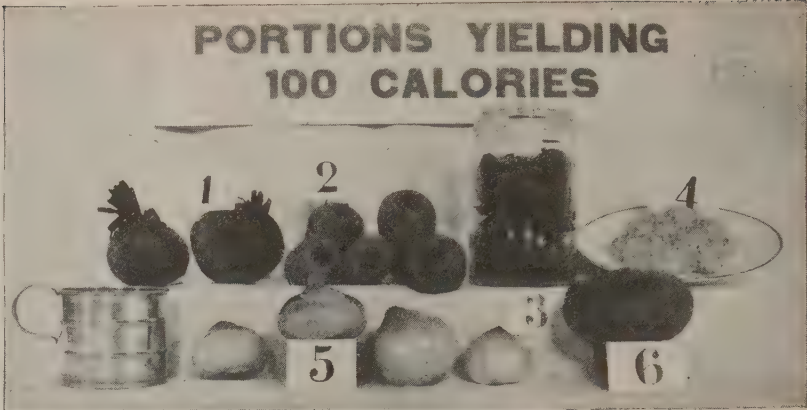


FIG. 4. 100-Calorie portion of peas
1. Dried peas
2. Dried peas soaked
3. Fresh green peas
All are in 8 oz. jars

Roots, tubers and bulbs may be regarded as reserves of nourishment for the use of the plant itself. Knowing this fact, it would naturally be expected that the vegetables included in this group would supply a larger quantity of actual food material than is found to be the case with green vegetables. The percentage composition of roots, tubers and bulbs shows that this is true.

For example, whereas the total of the solids of green vegetables do not amount to more than 8 per cent, the solids of roots and tubers are found to range between 10 per cent in the turnip and 30 per cent in the sweet potato. The carbohydrate averages between 15 and 20 per cent, the protein about 2 per cent, the mineral matter 1 per cent, while the fat, as in green vegetables, is present in almost a negligible quantity. The following table gives some idea of the caloric value of an ordinary serving of roots, tubers and bulbs (see figure 3):

DISTRIBUTION OF CALORIES IN 100-CALORIE PORTIONS

VEGETABLE	APPROXIMATE MEASURE OF 100-CALORIE PORTION	CALORIES FROM		
		Protein	Fat	Carbohydrate
Beets . .	3-4 servings	14	2	84
Carrots . .	4-5 servings	10	8	82
Onions . .	2-3 servings	13	6	1
Parsnips .	3-4 servings	10	7	83
Potatoes .	1 medium-sized	10.5	1	88.5
Sweet potatoes	About $\frac{2}{3}$ size of white potato	6	5	89
Turnips .	3-4 servings	13	5	82

From the figures it will be noted that the amount of protein yielded by a 100-Calorie portion of these vegetables is considerably less than is the case with green vegetables. The latter give between 20 and 30 per cent of the calories from protein, whereas roots and tubers average only between 10 and 15 per cent; the sweet potato, below 10 per cent.

Although the roots and tubers have not a high protein content a closer study will show that potatoes, at least, are a more valuable source of this constituent than green vegetables. For example, in comparing spinach with potato—the 100-Calorie portion of spinach (five servings) yields 35 per cent of the calories from protein while a 100-Calorie portion of potato (one serving) yields 10 per cent.

The mineral content of roots and tubers compares quite favorably with that of green vegetables, as may be seen from the following table:

MINERAL CONTENT IN 100-CALORIE PORTIONS

VEGETABLE	IN 100-CALORIE PORTION, WEIGHT OF		
	Calcium, gms.	Phosphorus, gms.	Iron, mgms.
Beets	0.064	0.084	1.30
Carrots	0.124	0.101	1.33
Onions	0.069	0.093	1.00
Parsnips	0.091	0.117	0.90
Potatoes	0.016	0.069	1.56
Sweet potatoes .	0.016	0.037	0.41
Turnips	0.161	0.117	1.27

The roots are a fair source of calcium, phosphorus and iron. The potato is poor in calcium, fair in phosphorus, but comparatively rich in iron. One serving (100-Calorie portion) of this vegetable will give one-tenth of the daily requirement of iron, about half as much as a small serving of spinach will yield. The sweet potato is equally poor in calcium and is also poor in phosphorus and iron. As a source of minerals, then, the sweet potato is of little value.

The high content of carbohydrate is an important characteristic of this group of vegetables, but owing to their bulk the roots are not of great value in the dietary as energy-producers, while the tubers are valuable from this standpoint. The potato is one of the chief commercial sources of starch. The sweet potato contains from 4 to 6 per cent of sugar and usually over 20 per cent of starch. The quantity of sugar increases and that of the starch di-

minishes on storing. The root vegetables contain more sugar and less starch than the potato. The beet is characterized by its richness in sugar. In the process of cooking, however, unless care is taken, much sugar is lost, so that the ordinary beet as it comes to the table may not contain more than 3 per cent. The vegetables of this group are sometimes classified according to the amount of carbohydrate they contain—for example, potatoes are a 20 per cent vegetable, parsnips a 15 per cent, while onions, turnips, carrots and beets are only 10 per cent vegetables.

Recent experiments have shown that this group of vegetables is an important source of the vitamins. Carrots were found to be rich in both vitamin A and vitamin B. For example, on a diet containing 10 per cent of carrots, sufficient vitamin B was supplied for the growth of rats. When 15 per cent was used there was a sufficient supply of vitamin A as well. Investigators have found parsnips, beets and potatoes to be very poor in vitamin A but to contain a good supply of vitamin B. Yellow sweet potatoes were found to contain sufficient vitamin A for growth, but were deficient in vitamin B. A few of the roots and tubers have been shown to have good antiscorbutic power—namely, the potato, carrot, turnip and onion. It was found that potatoes still retained considerable antiscorbutic value after cooking for one-half hour at 212°F. They have been proved to be an excellent and cheap antiscorbutic. It is evident, then, that roots and tubers are a comparatively good source of vitamins, especially of vitamin B and of vitamin C.

It is the prevailing idea that rice is a good substitute for potatoes. A comparison of the two will show that this belief must be modified. Polished rice, for example, contains no appreciable amount of the minerals and it is lacking in the vitamins, possessing absolutely no antiscorbutic power. Potatoes, on the other hand, though deficient in calcium yield a large amount of iron; though lacking in vitamin A, they possess a good supply of vitamin B, and are excellent as antiscorbutics.

From another point of view also rice is a poor substitute for potatoes — it leaves an acid residue in the blood while the potato contains an abundance of base-forming elements and leaves an alkaline residue.

With a few exceptions (notably the ordinary potato) the amount of cellulose contained in one serving of roots and tubers is higher than that of green vegetables. For example, parsnips and sweet potatoes contain over one gram in one serving, spinach three-quarters of a gram.

Legumes. In the dry bean seed and also in the pea and lentil the young plant lies dormant with a large supply of all the foodstuffs ready for its first growth in the spring. Considering this fact, one would naturally expect to find in the legume an appreciable amount of all the foodstuffs necessary for growth. The high percentage of total solids — 85 to 90 per cent — shows that dried legumes represent a more concentrated type of food than any of the other vegetables. The various food constituents are found to be present in much larger amounts — for example, the protein varies between 22 per cent in the ordinary bean to 37 per cent in the soy bean; the carbohydrate averages about 60 per cent in all but the soy bean, the mineral matter from 2 to 5 per cent; while the fat averages 1 per cent in all legumes, with the exception of the soy bean, which contains as much as 18 per cent. While the dried form of this type of vegetable shows a very low percentage of water, a great deal is absorbed in the cooking, so that in reality legumes are a much bulkier food than their low water content would indicate.

DISTRIBUTION OF CALORIES IN
100-CALORIE PORTIONS

VEGETABLE	APPROXIMATE MEASURE OF 100- CALORIE PORTIONS	CALORIES FROM		
		Protein	Fat	Carbohy- drate
Beans — Navy	1 serving	26	5	69
Beans — Lima	1 serving	21	4	75
Beans — Soy.	1 serving	41	45	14
Lentils	1 serving	29.5	2.5	68
Peas — Dried	1 serving	28	2	70
Peas — Green	$\frac{1}{3}$ pint	28	4.5	67.5

The preceding table shows that in the distribution of calories, legumes are not unlike green vegetables but they differ considerably in the caloric value of an ordinary serving portion (see figure 4).

The striking characteristic of the legumes is the high percentage of protein. In fact they contain a larger amount of this constituent in one serving than any other form of vegetable food. The legumes secure their nitrogen, which is the characteristic element of protein, from the free nitrogen of the air. This is accomplished by the workings of certain bacterial organisms found in the nodules on the roots of these plants. The legumes appear to be the only plants capable of making use of the nitrogen of the air for food purposes.

The legumes, therefore, may be classed with the protein-rich foods. It is shown in the table that peas, ordinary beans and lentils are very similar in the amount of protein contained in one serving. The soy bean, however, stands out alone as being exceedingly rich in this constituent. This bean has recently been introduced into the United States from Japan. It is characterized by the very high percentage of protein and fat and the small amount of carbohydrate and cane sugar. On account of the very low carbohydrate content soy bean flour is widely used in the feeding of diabetic patients. Since protein food is usually expensive, it would seem that in soy beans and other legumes there is found a cheap and abundant source of this nutrient. To a certain extent this is true, and beans have been extensively utilized for this purpose. It happens, however, that the protein of legumes, with the exception of soy beans, is not so suitable for growth as that of milk, eggs or even wheat. In fact it is graded as only a "C" protein, while the proteins of milk and eggs are classed as "A" and that of wheat as "B." Taking this fact into consideration, it is a somewhat erroneous idea that legumes are a perfect substitute for meat in the diet. In order to make them so they must be supplemented with some grade A protein such as milk or eggs. The proteins of soy beans have been found to be of grade A quality.

The legumes, with the exception of soy beans, contain a large amount of carbohydrate but are poor in fat. For this reason they go well with fatty foods and are improved by being served with sauces containing butter. When cooked, legumes contain about the same per cent of starch as potatoes and like potatoes are classed as 20 per cent vegetables. The mineral constituents are fairly abundant, as shown by the following table (based on Sherman's figures):

MINERAL CONTENT IN 100-CALORIE PORTIONS

VEGETABLE	IN 100-CALORIE PORTION, WEIGHT OF		
	Calcium, gms.	Phosphorus, gms.	Iron, mgms.
Beans — Navy . .	0.047	0.137	2.03
Beans — Lima . .	0.020	0.096	2.00
Lentils	0.031	0.126	2.47
Peas — Dried . .	0.024	0.112	1.60
Peas — Green . .	0.028	0.127	1.70

Though comparatively poor in calcium, legumes are quite rich in iron. One serving of peas, about three-quarters of a serving of beans and slightly less of lentils will each supply one-tenth of the daily iron requirement. An ordinary serving of legumes is therefore a richer source of iron than a similar portion of root vegetables and compares very favorably with potato. The potato, however, has the advantage because of its extensive use. The vitamins are not so well represented in the legumes as in the other groups of vegetables. Though lacking in antiscorbutic power and deficient in vitamin A, they possess vitamin B in abundance. The amount of cellulose contained in these vegetables is higher than in any of the other types. However, since the greater part of this is in the skin, which is often removed before eating, the actual amount of cellulose obtained may be very much smaller.

Digestibility

The true value of food does not depend alone on the contained nutrients, but also on the ease and completeness with which the system utilizes these nutrients. Leg-

umes on the whole are not readily digested and are found to remain in the stomach a long time. Those in the green state seem to be more easily digested than the dried. Although legumes require more work on the part of the digestive tract than many other foods, experiments show that they are ultimately well utilized. The amount digested was found to vary with individuals, 86 per cent of the protein being digested in one case and only 72 per cent in another. The protein of beans is not so completely utilized as that of meat. Experiments show that when beans are combined with other foods — forming only a part of a ration — they are more completely digested than when used in large amounts as the main article of diet. Flatulence, which so commonly accompanies the digestion of beans and other legumes, is probably due to the sulphur contained in these vegetables, which gives rise to the formation of gas.

The potato, owing to its readiness to undergo fermentation, should be avoided in some diseased conditions, such as dilatation of the stomach. The digestibility in mouth and stomach depends largely on the mastication and thorough mixing with the saliva. Potato is more slowly digested when taken in lumps than in a puree and a "mealy" potato is said to be more easily digested than a "waxy" one. In Robert Hutchison's "Food and Dietetics", the author states that one potato weighing $5\frac{1}{3}$ oz. (a medium-sized potato) when boiled and eaten in the usual way remained from 2 to $2\frac{1}{2}$ hours in the stomach. Further digestion takes place in the intestines and the end products are well absorbed, since there is very little indigestible cellulose.

In regard to the digestibility of green vegetables, much depends upon their condition when eaten. For example, if the cellulose is too abundant, fibrous or tough, the vegetable may prove irritating to the digestive tract. On the whole this type of vegetable is not easily digested by the stomach. Hutchison states that a portion of cabbage weighing $5\frac{1}{2}$ oz. requires 3 hours, while the same weight of cauliflower takes only $2\frac{1}{4}$ hours. Fermentation

frequently occurs in the intestines when these vegetables are a little stale. To be wholesome they should always be eaten as fresh as possible. The absorption of nutrients of most of these vegetables is rather defective — in fact, they constitute one of the few forms of food from which even digestible carbohydrate is not completely absorbed. This is no doubt due to the proportionately large amount of cellulose present. This cellulose is, however, of very great value in the successful carrying on of digestive processes. To insure the normal and regular passage of the food through the lower part of the digestive tract a certain amount of undigested but non-irritating material is advisable and the cellulose provides this. Some solutions of mineral salts have the property of hastening the passage of food through the intestines and it seems possible that, in part, these vegetables owe their well known laxative properties to the specific nature of their juices.

Preparation for the table

In the preparation of vegetables for the table the waste should be as small as possible. There is always a small or large loss due to the inedible matter but as a rule a waste of good material is commonly caused by careless preparation. The amount of refuse varies greatly in different vegetables. It may be as small as 7 per cent in such vegetables as string beans; medium, 10 to 15 per cent in onions, cabbage, lettuce and cucumbers; or high, 50 per cent in peas in the pod, pumpkin and squash. With tubers such as potato the average amount of refuse is 20 per cent. In preparing vegetables it is, of course, necessary to remove all this inedible portion, but at the same time, one should see that the total amount of refuse is as small as is consistent with good quality. Thinning of potatoes and other vegetables is an economy which it is worth while to practise and is an easy way of decreasing useless loss.

There are several important principles to be kept in mind when cooking vegetables. First, there must be a softening of the fiber in order that the digestive juices

may more readily penetrate the food constituents. Second, the opening of the starch granules will render the starch more easily available. Third, these two ends should be accomplished with as little loss of flavor and of the mineral constituents as possible.

The different cooking processes used are ranked according as they fulfil this desideratum. Baking conserves most material, then come steaming, stewing and boiling. For example, when cabbage was boiled it was found to lose 32 per cent of total solids, but when steamed only 9 per cent. With potatoes it was found that when they were boiled in their jackets the loss of material was trifling but when pared and soaked for several hours before boiling the loss amounted to 50 per cent of the protein and 40 per cent of the mineral matter. If not allowed to soak but cooked at once the loss was considerably decreased, being then 8 per cent of protein and 18 per cent of mineral matter. With all vegetables the loss in cooking is found to be greater when they are cut in small pieces.

In view of the fact that so much nutritive material and particularly mineral matter is lost when the commonly used method of boiling is employed, too much stress cannot be laid on the importance of the vegetable water. To a great extent we depend upon vegetables for our supply of mineral matter but if we do not make use of the vegetable water it would seem that our diet must suffer. If it is not desired to use this water in soups or as the foundation of a sauce, then some method of cooking other than boiling should be employed to avoid this useless loss of valuable nutrients.

It is very important to avoid overcooking vegetables as it has the effect not only of toughening the texture of such foods but also of destroying the coloring matter and the flavor. Overcooked vegetables are inferior in appearance and flavor and are often indigestible as well as unpalatable and of less food value.

The special value of vegetables in the diet may be summed up very briefly more or less as follows:



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LARGEST TRUCK FARM EAST OF THE MISSISSIPPI

Five thousand acres in Cumberland County, N. J., under cultivation. Note overhead irrigation pipes.

Green Vegetables. The value of green vegetables lies in their abundant supply of minerals (especially iron), widespread distribution of the vitamins, high percentage of water, large amount of cellulose and the low content of protein, fat and carbohydrate which is an actual advantage in enabling one to balance a dietary by adding these foods without either making protein or energy intake excessive. These vegetables are also base-forming and are of great value to the body in maintaining the normal neutrality of blood and tissue.

Roots and Tubers. It may be said that the vegetables in this group are valued chiefly for their store of minerals yielding base-forming elements, abundant supply of the essential vitamins and high content of water and cellulose. The tubers are valuable as a source of carbohydrate.

Legumes are valued as a concentrated form of food, containing as they do more available food material in a serving than any other vegetable except potato.

Vegetables provide the bulk and roughage desirable for normal digestion and add variety and attractiveness to the diet.



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GROWING CABBAGES IN SOUTHERN NEW JERSEY

FIVE HUMAN SPECKS ON A GLACIER



A PARTY OF FIVE TRAVELERS CROSSING THE GIANT GLACIER FROM MONT MAUDIT

This photograph and those on pages 3449 and 3451 are by Donald Macleish.

THE SOLID WATERS

The Crystallization of Snow and Ice; the Flow
of Glaciers and the Formation of Icebergs

DO THE WORLD'S ICE RESERVES LESSEN?

ONE of the most remarkable things about water is the facility with which it changes from vapor to liquid, from liquid to solid. We have already discussed its properties as vapor and as liquid; let us now consider its behavior as a solid.

Almost all substances, as we know, contract in bulk as they diminish in temperature, and water down to a certain point does the same. From 212° F. to 39° F. water shrinks as it cools, but below that point it expands as it cools, and at 32° F. it changes into solid crystals, with a further increase of 8 per cent in its bulk. If a pail filled to the brim with water weighs 10 pounds, the same pail filled to its brim with ice will weigh only 9.16 pounds. Since the water expands as it freezes, and since ice, bulk for bulk, is lighter than water, it follows that ice is formed first on the surface of water, and that ice floats in water. Even a mountainous iceberg will float, and on account of the inclosed air bubbles about one seventh instead of one ninth of its bulk will be above water.

The importance of this we have already mentioned. Did water not expand but contract on cooling, did ice not float, then ice would be formed in the first place at the bottom of water. Accordingly, since water is a very poor conductor, and since warm water does not sink, the heat of the summer sun would not reach the ice in the depths. Winter after winter would add layer on layer of ice, and eventually all the water in the world would be solid ice. The climatic and biological results of this are evident, and it is plain that the anomalous

behavior of water in expanding before and during freezing is of great advantage to the world as a habitation of living things.

At freezing-point, as we have said, water becomes converted into solid crystals, and these crystals, according to circumstances, may form ice or snow. The crystallization of water on passing from the fluid to the solid state is no unique phenomenon; indeed many substances are commonly found in a crystallized state, like sugar, salt, sulphur and alum. The size of any crystal is of no importance; the same substance may exhibit microscopic and huge crystals. Quartz crystals, for instance, are found so small that they can be seen only through a microscope, and so large that they may weigh over a hundred pounds. And any minute crystal will grow indefinitely in size by a deposition of more substance on its exterior. The important and distinguishing feature of crystals is not their size but their shape, and especially their interfacial angles, that is, the inclination which one facet bears to another.

The crystals of snow are known to everyone. Who has not caught snow on his sleeve to examine the delicate rays of the crystal against a dark background? On examination it will be found that there are numerous varieties of snow crystals, yet each is regular and symmetrical, and each has six rays or angles, neither more nor less. W. A. Bentley, of Jericho, Vermont, has photographed more than a thousand different forms of snowflakes, but all of them belong to the same crystalline system.

Ice, like snow, is crystalline in structure; it is made up of crystals interlocked and interlaced. We cannot see the individual crystals in solid ice, but if a block of it be melted with a burning-glass it will be found that the melted crystals leave little spaces shaped like tiny flowers, each with six petals. In the beautiful ferny patterns traced by the frost on our window-panes it is easy to demonstrate the crystals. Even hail can be shown to consist of crystals.

The part played in the economy of nature by solid water is a very important one. In many parts of the world snow and ice are perpetual, and occur in such large quantities that they may quite legitimately be considered as crystalline rocks. In the Arctic regions there is constant snow and ice, and even in tropical and sub-tropical countries, at a certain height above sea level, snow and ice last the whole year round.

The level above which snow persists, the "snow-line", varies with the latitude and with other circumstances. On the north side of the Himalayas it is about 16,600 feet; in the Andes of Peru about 15,500 feet; in the Alps, about 8500 feet; and in the northern Norwegian mountains, about 3000 feet up.

What should we see on a mountain fifty thousand feet high?

But the snow-line varies from place to place on the same mountain range, and from year to year on the same peak. Probably if a mountain rose to 50,000 feet or so, it would have little or no snow on its summit, since all the moisture of the atmosphere would be condensed before it had risen so high. In the Alps, indeed, the greater bulk of the snow falls at an altitude of between 6000 and 9000 feet. At the Hospice of Grimsel, which is situated at an elevation of 6048 feet, 57½ feet of snow, equivalent to 5 feet of water, have been recorded during six winter months. At the St. Bernard Hospice (8110 feet), the annual depth of snow varied during twelve years from 11½ to 44½ feet. At some places 6 or 7 feet of snow have fallen in a single night.

On the average about 30 feet of snow falls every year on the high Alpine peaks. Thirty feet of snow annually would in a thousand years grow to thirty thousand feet, if the snow remained and accumulated from year to year. But it does not accumulate; it is melted and evaporated by the sun, and it slides down the mountain-sides as avalanches and glaciers.

The ways in which the winter snows disappear from mountains

Rain and mist and wind also serve to dissipate it in various ways. In one day a hot sun or the warm winds, called "*foehn*" or "*chinook*" winds, can melt over two feet of snow, and a hurricane can remove thousands of cubic feet of snow. It should be noted that snow can be completely removed by evaporation without passing through the liquid state and hence without any appearance of actual thaw. All those who ski and toboggan are well acquainted with this slow, steady evaporation of the snow.

The masses of snow which slide suddenly down mountain slopes are known as avalanches. Avalanches are of two kinds — "dust" avalanches, consisting of finely powdered, loose snow; and "ground" avalanches, consisting of masses of more coherent snow. It is difficult to say which is the more dangerous. Both gather volume and momentum as they descend, and may finally acquire such pace and impetus as to sweep away villages, break away rocks, and uproot trees merely by the blast of compressed air which precedes them. An avalanche from the Pyrenees in 1846 leveled more than 15,000 pine-trees.

Were it not for trees on the slopes of mountains, avalanches would work still more havoc, and many plantations are specially set out for purposes of defense. So important as natural defenses are the trees that at one time any man found guilty of destroying a tree in the valley of Andermatt was put to death; and it was popularly believed that drops of blood oozed from any branch intentionally broken, a superstition alluded to by Schiller in his "*Wilhelm Tell*".

PEAKS FROM WHICH GLACIERS DESCEND



© Fred H. Kiser, Courtesy National Park Service

HEAVENS PEAK FROM THE GARDEN WALL, GLACIER NATIONAL PARK



© Fred H. Kiser, Courtesy National Park Service

MOUNT JACKSON (10,023 FEET), GLACIER NATIONAL PARK

In places subject to avalanches, man, besides planting trees, has usually erected walls and basket works. But all snow that slides down a mountain does not do so suddenly and violently as an avalanche. More commonly it moves slowly downhill, becoming more and more compressed as it descends. At first the snow consists of loose, frozen granules, then the granules are compressed into a compact mass known as "*névé*" or "*firn*", and eventually the mass is converted into blue, compact glacier ice. The change of snow into ice is mainly a matter of compression — a change

and the pressure of the mass above and behind them. In 1827 a hut was built on the Unteraar Glacier and its position marked; in 1841 it was found to have moved 1561 yards down the valley, or at the average rate of 112 yards a year. The Finsteraar and Lauteraar glaciers, tributaries of the Unteraar Glacier, were found to have a central flow of about 80 yards a year. The Mer de Glace on the slope of Mont Blanc, near Chamonix, France, moves much more rapidly. At the base of the Montanvert its rate is 822 feet annually, and its mean daily rate



ICE-FLOWERS ON ST. MORITZ LAKE, FORMED BY THE THAWING AND REFREEZING OF ICE

of much the same nature as that of the snow on our heels into lumps of ice.

Though the snow in the course of its descent is converted into glacier ice, the ice is not stationary; the whole glacier flows downwards like a river. If a row of stakes be planted in a line across a glacier, it will be found that the stakes will slowly be carried along downhill, the central stakes moving more quickly than the lateral ones; showing that, just as in a river, the flow of a glacier is quickest in the middle. Different glaciers flow at different rates, depending on the slope of their beds

in summer and autumn is from 20 to 27 inches at the middle, and 13 to 19½ inches at the sides. Faster still flow the glaciers from Greenland's icy mountains. One at Jakobshavn Fiord was found during the summer to advance at the rate of 65½ feet a day, and another flowing into the sea at the bay of Angpadlartok at no less than 100 feet in 24 hours.

On several occasions the rate of flow of glaciers has been demonstrated in dramatic fashion by the recovery of the bodies of men who have fallen in the clefts of a glacier.

In 1820 three guides fell into a deep crevasse in the Glacier des Bossons, which only in 1861, 1863 and 1865 gave up their bodies. In the interval it was found that they had traveled about $3\frac{3}{4}$ miles, or about 160 yards each year. In 1860 an Austrian glacier gave up a corpse clad in a garment centuries old, showing how long it must have lain in its icy embrace. It must be understood, however, that no glacier flows at the same rate from top to bottom, but that its rate of flow varies like that of a river, and for the same reasons.

The movement of glaciers is more probably explained by the fact that ice melts under pressure, to freeze again when the pressure relaxes. According to this theory ice is successively freezing and melting, fracturing and mending. A simple experiment, often used, illustrates the melting of ice under pressure, and its regelation when the pressure is removed. A heavy weight is slung over a block of ice by a loop of wire. The pressure of the weighted wire melts the ice under it, and as the wire cuts through the ice the pressure it exerted is removed



TRAVELERS ON THE BOSSONS ICE-FALL

It is rather a remarkable thing that a mass of hard blue crystalline ice should actually flow like a river, and the nature of the flow is not yet fully understood. It was formerly supposed that ice is a plastic substance, and that under tremendous pressure it would flow as resin or pitch might, accommodating itself to the irregularities and inequalities of its bed. This viscosity theory is more difficult to believe when we consider that glacier ice is really composed of grains of ice from the size of a pea to the size of a melon, and is not a homogeneous mass.

above it, and so the melted ice freezes again; and when the wire has gone right through the block the latter is found unbroken.

Though the glacier travels with a kind of flowing motion, it never preserves entire continuity. Always stretching obliquely from the margin towards the middle of the stream, there are fissures known as "crevasses". At first these fissures point upstream, making an angle of 45° with the bank, but the movement of the glacier soon disturbs their original direction, and may eventually produce an irregular network of crevasses.

The fissures, moreover, are not permanent; they usually soon close up again, though a few may widen and persist as great, yawning chasms, which may be hundreds of feet deep. The intersection of glaciers by crevasses sometimes leads to the formation of fantastic blocks and columns of ice which may resemble animals, or spires, or turrets. The tower-shaped structures are known as "*séracs*". In winter the crevasses are filled up with

there are many of colossal size. In the United States there are many in the mountainous regions along the Pacific Coast, especially on the slopes of Mount Shasta, California, and Mount Rainier, Washington. In Glacier National Park, Montana, there are some ninety, and though these are of comparatively small size—the largest having an area of about 3 square miles—they are very fine examples of glacier formation. Larger gla-



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ABOVE THE CLOUDS ON THE CREST OF THE DOLOMITES, AUSTRIA

snow; and when summer comes part of the snow remains, forming bridges, often unsafe, but often useful to mountaineers.

In every country with snow-mountains, glaciers abound. In Switzerland there are no less than 2000, averaging from three to five miles in length. The great Aletsch Glacier is over a mile broad, and nearly ten miles long, and the Gorner Glacier, 9.4 miles long, covers an area of 26.6 square miles. In Scandinavia glaciers are equally plentiful, and in the Himalayas and Andes

ciars are found among the Canadian Rockies, and in Alaska there is the mighty Muir's Glacier, which, with many others, flows into Glacier Bay. Where it issues from the mountains, it is more than 2 miles wide. "Nine large and seventeen smaller branches unite to form the main ice-stream, which to the extent of a current 5000 feet wide and 700 feet deep, enters the sea during the month of August at the rate of 70 feet a day in the center, and 10 feet in the margin."

ICY ABYSSES OF THE MONT BLANC RANGE



A CREVASSE EIGHT HUNDRED FEET DEEP ON THE GLACIER DU GÉANT, NEAR CHAMONIX

A glacier usually ends gradually tapering away as it descends, and from its termination gushes a stream formed partly by the melting of the glacier itself, and partly by streamlets which have poured on to it from the hills and have tumbled down its crevasses. The thawing of the glacier limits its downward career, and during the summer, indeed, it retrogresses and thins out. In Switzerland, the daily average summer retrogression is 3.62 inches, and the daily summer subsidence 1.63 inches. In the winter the glacier lengthens and thickens again.

Are glaciers increasing or diminishing, or do they fluctuate in size?

At this point the question naturally presents itself—are modern glaciers advancing or retreating, increasing or diminishing? No certain answer can be given to this question. In most cases there has been an alternate advance and retreat, increase and diminution. For instance, in Switzerland, where they have been long under observation, they retreated during the middle decades of the last century, advanced again during the last decades, and now seem to be retreating again.

Between 1854 and 1869 the Glacier des Bossons receded 332 meters, that of Bois 188, that of Argentièrre 181, and that of Tour 520. Between 1871 and 1875 every Alpine glacier receded. In 1875 a pretty general advance began, and during the last few years of the century the Glacier des Bossons advanced at a rate of over 160 feet. In 1899 the advance began to halt, and at present all over the globe, with few exceptions, glaciers are receding.

The enormous size of polar glaciers and ice barriers

In certain respects, the polar glaciers form a class by themselves, in that they flow into the sea, and break up into icebergs. Some of them are of huge size. The Humboldt Glacier, in North Greenland, has a frontage of 66 miles. The Dove Glacier in the same region is about as large, while the Eisblink pushes a tongue of ice 13 miles long into the sea.

The whole of the antarctic continent, a continent as large as Europe and Australia combined, may be considered a glacier or a congregation of glaciers, for it is covered with the accumulated snows of centuries which have been turned into ice by pressure; and the ice by its own weight is slowly and constantly slipping into the sea. The great Ross Barrier, south of New Zealand, shows the character and constitution of the continent. It is a great white cliff of ice, sometimes reaching 100 feet in height, which stretches east and west for a distance of 300 miles. Though not resembling a typical tongued glacier, this great wall of ice is in fact and act a glacier, since it is constantly flowing onward, impelled by the weight of ice behind it. One great feeder is no less than 415 miles from the sea.

When the ice of a glacier reaches the sea it usually creeps at first along the sea bottom, but after a time its superior buoyancy forces it upwards, and under the strain the glacier fractures, and a great mass of ice is broken off, and floats in the sea as an iceberg.

An iceberg large enough to block up half of Long Island Sound

Icebergs are stupendous. Those broken off from the Jakobshavn ice-field in North Greenland sometimes rise over 600 feet above the sea, which means that the total height of the iceberg from base to summit is about 4000 feet. Hayes measured an iceberg 315 feet high above the water, and more than three quarters of a mile long, and calculated that it weighed 2,000,000 tons. Ross and Parry described one 153 feet high and $2\frac{1}{2}$ miles broad, which might weigh about 1500 million tons. The antarctic icebergs are not so high as the arctic, but some are of enormous extent. William Speirs Bruce, the leader of an antarctic expedition in 1902-4, declares that he saw many icebergs at least a mile long, that on one occasion he measured one 12 miles long and that "on another occasion the *Balæna* steamed at the rate of five knots for six hours along the face of a berg, which made the length of it fully 30 miles."



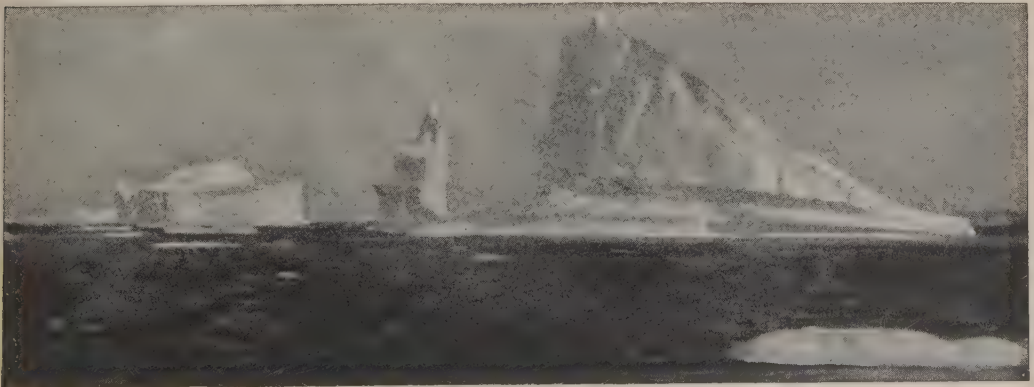
HOW ICEBERGS BREAK AWAY FROM A GREENLAND GLACIER

Such enormous masses of ice may float for great distances before they melt. Icebergs from Greenland may get as far south as the coast of Spain, and those from the antarctic glaciers may get as far north as the Cape of Good Hope. The number that cruise about the sea must be very great. In Baffin's Bay, Dr. Kane once counted a pack of 280 bergs. Dr. Bruce counted 60 from the deck of the *Balena*. During the winter of 1903 a constant procession of icebergs drifted past the South Orkneys for eight months.

Even in the track of the great North Atlantic liners icebergs in great numbers may be seen during certain months of the year, and many a good ship has been ripped and wrecked by the mighty ice crags. South of Newfoundland the floor of the ocean must be littered with ships and dead men's bones, for here, in the mists that hang around these regions, many ships have gone to their doom. Here the *Titanic*, April 14, 1912, collided with an

iceberg and was lost, with 1517 out of the 2223 on board.

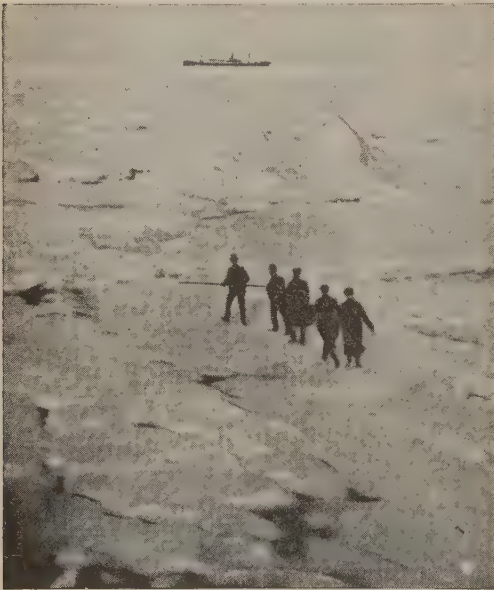
Dangerous and formidable as they are to the mariner, icebergs have a beauty, a grandeur, and a solemnity that appeal to the beholder. "Their stupendous size," says Dr. Bruce, "their exquisite architectural composition, more magnificent than the temples and pyramids of Egypt, more overpowering in solemnity than the Sphinx, make the most thoughtless think for a moment of the Power that controls the forces of nature. At one time we passed through a regular street, lined on each side with towering bergs, each a temple in itself, now Doric, now Egyptian, each perfectly carved and shaped, each purer and whiter than the other, glittering in the sun, pearl-grey in the shade, and rich blue in the clefts and caves which pierced their sides. This street or avenue was several miles long; indeed, some individual bergs were fully half a mile in length. Side avenues opened into this main avenue."



ICEBERGS FLOATING PAST NEWFOUNDLAND, SOUTHWARD BOUND

Bergs are more dangerous to mariners when they are massive and unmelted, but even when they are melted down to fractions of their original selves they remain perils of the deep. The final remains are known as "growlers" and "bergy bits". They are particularly hard ice, and many is the good ship they have ripped up. Bergs and bergy bits are also indirectly dangerous, in that they condense moisture and cause sea-fogs.

Besides the ice formed from snow by compression, there is, of course, ice formed directly from water by the action of frost.



ICE-FLOES OFF THE COAST OF LABRADOR

In some latitudes the rivers, lakes and inland seas freeze in winter and thaw in summer; in other latitudes there is frozen water all the year round. Examples of the first sort are seen in the Siberian rivers, in the Baltic, and the St. Lawrence with its lakes. Examples of the latter sort are seen in the arctic and antarctic regions.

In Canada the ice on the lakes and rivers is one and a half to two and a half feet thick. When river ice breaks up, it rends and tears the banks of the river, and wears down any islands in the middle of the stream. Sometimes a river gets dammed up with heaps of broken ice; and when eventually it bursts the dam it may work great destruction.

As a rule, ice forms on the surface of rivers, but sometimes on the bottom. The reason of this is supposed to be that the cold water of the surface is mixed by the currents into the general body of the water, and so the river is uniformly cooled down to freezing-point. That being so, the stiller bottom water in contact with cold stones freezes first. This ground ice, sometimes known as "anchor-ice", often floats to the surface, and lifts with it stones, gravel, sand and other materials to which it is attached.

The ice formed on the surface of the sea is of special interest. Not till the temperature falls to 28° F. or thereabouts does the sea freeze, and when it does it forms an ice differing in many ways from land ice. If the surface of the open sea be observed when the temperature falls to 29° F. and lower, it will be found to be overspread with delicate spicules; and if the temperature keeps low these will increase until they form a layer two or three inches deep. A layer of fresh-water ice two or three inches thick is strong enough to skate upon, but a layer of sea ice of the same thickness is soft like glue, and will not bear a child; in fact, a seal can easily poke its nose through, and an ordinary ship can plow through it. If snow falls upon such a layer, the ice spicules and snow crystals lock together, and the depth of the layer is increased; and very often the earliest layer of ice on polar seas is of this mixed nature. It is known as "bay ice", since ice is formed first in sheltered bays, or "black ice", because it is black and translucent.

Naturally such ice is fragile; and soon, under the heaving of the tides and the threshing of the winds, it is broken into hexagonal fragments a few inches or feet in diameter. These hexagonal discs again get crushed and knocked about, and thicken with the frost, and become what is called "pancake ice". The pancakes, again, get frozen together into a rough, tessellated pavement, and this, in turn, is broken into bigger hexagons, which again are congealed together. Finally a pancake patchwork of thick, white ice is formed strong enough to resist the

efforts of the sea to break it. If the sheet is large it is called "floe ice"; if it extends continuously farther than the eye can see, "field ice". But a distinction must here be made. This is floe ice or field ice of the first season — *débutante* ice, so to speak. But floe ice and field ice are not always formed *de novo* out of sea water; they may be formed out of fragments of the former winter's new ice when it breaks up in the summer. In this case, when the floe ice or field ice is not born of bay ice, but built up out of fragments of former floe ice or field ice, it is much rougher and stronger.

When sea water freezes the ice is found to have rejected about four-fifths of the salt which was originally present; and though there may be some brine on the surface, the ice below when melted is almost pure water, and is quite good for drinking and washing purposes. Almost all antarctic ice has a yellowish-brown layer sandwiched in it just about sea level. Pack ice, floe ice, berg ice — all show this colored layer. In arctic ice the same layer occurs, but it is more superficial. When examined it is found to consist of myriads of microscopic plants called "diatoms", which make the ice their home.



BOATS PLOWING THEIR WAY THROUGH THE ICE-STREWN WATERS OF LAKE MICHIGAN

When fields and floes break up they first fracture into small floes, but these again split up into fragments mostly a few feet in diameter. In this condition the ice is known as "pack ice". Pack ice drifts before the wind in mighty streams with irresistible power until the separate pieces are again welded by frost into fields or floes. Often the pieces are hurled together in heaps; and when they freeze together we get what is known as "hummocky ice". Round the margins of pack ice there is usually a collection of much smaller fragments, known as "brash ice".

Since the layer spreads for hundreds and hundreds of miles, it represents a tremendous population of diatoms. Curiously enough they serve as protective coloring for the polar bears, which in their winter pelage are a light yellow, closely resembling the color of this layer, and, even at a moderate distance, hardly to be distinguished from it.

In some parts of the polar regions, especially in Spitzbergen and Nova Zembla, acres of snow and ice are colored red. This is due to the blood-red microscopic alga *Sphaerella nivalis*.



DISASTROUS EFFECTS OF HAIL

Photograph of a corn crop almost completely destroyed by a hail storm which covered an area about 20 miles long by 3 miles wide.

It is remarkable that, even in ice, life should survive. Dr. Bruce melted pieces of wet soil and moss that had been subjected to a temperature of -45° F. and as soon as they were melted myriads of minute creatures sprang into activity, and "a small nematode worm, that had evidently been on the point of laying its eggs when overtaken by the frost months previously, began to lay them as soon as it had melted out, and continued its life as if nothing had happened during this long period of sleep".

Hail may be briefly mentioned. It consists of little particles of ice which fall from the upper atmosphere. Hail falls in summer rather than in winter, and by day rather than by night, and is difficult to explain. It is probably formed of raindrops

which have been carried up into the colder higher regions of the atmosphere, and frozen there. Though usually about the size of small shot, hail may occur in pieces several inches in diameter, and a hailstorm in such a case may do great damage to fields and flocks, especially as hail falls in its more destructive forms only in the summer, when the crops have reached a stage in which they are easily damaged. Often hailstorms are accompanied by violent winds, which add to their dangers. It has been calculated that the damage done by a single storm, of unusual dimensions and persistence, has amounted to four or five million dollars; and in the course of such a storm stones weighing as much as three pounds apiece have been precipitated from the sky.

ON THE MICROBE'S TRACK

The Fascinating Life and Work of the
World's Greatest Chemist: Louis Pasteur

MAN'S SUPREME PHYSICAL BENEFACTOR

WE now come to the name of a great man, seldom thought of as a biologist, to whom, nevertheless, the science of life is immensely indebted, and who must certainly rank beside any of those whose work we have already discussed. Similarly, we shall find that Louis Pasteur must rank with or above the greatest doctors of all time, though he was not a doctor. He holds a place apart, at the foundation of many modern sciences, for none of which was he educated or specially prepared. For he began life as a chemist, and all his subsequent researches really spring from a chemical view of the problems of biology and medicine.

Early in our study of life we saw that there are processes of fermentation which play a large part in it, but how large no one can know who has not followed the work of the last few years. There are some who say that "life is a series of fermentations", which is probably true of the physical processes associated with life. Plainly, then, we want to know what fermentation is. When Pasteur began his work the dominant view was that of the great chemist Liebig, who was some twenty years his senior. His theory was that fermentation is a chemical phenomenon, due to certain chemical agents called ferments, probably acting in association with the oxygen of the air.

Then came upon the scene Louis Pasteur (1822-1895), who had been trained in Paris under some of the greatest chemists of the day. His genius for original research showed itself at once in connection with the behavior of crystalline salts of tartaric acid.

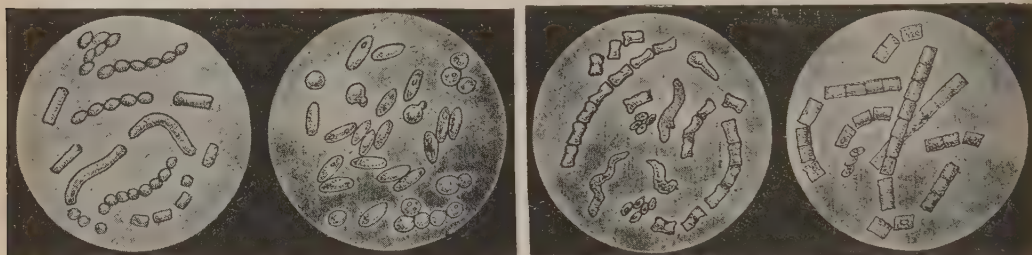
Students of optics all know that it is possible to polarize light in such a way that all its vibrations are in one plane, instead of being in all planes at right angles to the onward path of the light. It is found that, when a ray of such polarized light is sent through certain substances, they twist or rotate the plane of the vibrations, sometimes to the right and sometimes to the left. Such substances are called, respectively "dextro-rotatory" and "lævo-rotatory". Ordinary tartrates have no influence on polarized light, and are said to be "optically inert"; but the young Pasteur found that a certain microbe (the familiar word was introduced by him) feeds upon or ferments a solution of tartrates in such a way that they become lævo-rotatory, or left-handed. The solution, he discovered, began by being a mixture of the two kinds, right-handed and left-handed, in such proportions that the ray of light was not rotated in either direction on passing through them. But the microbe ferments the right-handed molecules, so that the solution now becomes left-handed. This is a true fermentation, and it is effected by a living plant. That was Pasteur's initial discovery; and all the rest, including the triumphs of Listerian surgery and many great things yet to come, are due to it.

Let us briefly note, in passing, what this discovery meant for chemistry itself, for recent developments of it may serve biology as much as anything that we are about to study. Pasteur showed that the molecule of tartaric acid may exist in two forms, exactly identical, except that one is, so to speak, the mirror-image of the other.

They differ, in a word, just as a right hand does from a left. This gives us the idea of chemical molecules as *solid* things, existing in three dimensions, and requiring to be studied from the point of view of their solid shape, as well as of their constitution. Hence Pasteur's initial discovery founded what is now called "stereo-chemistry" — that is, *solid* chemistry — which is beginning to win great triumphs. Its aid is essential in the realms of organic chemistry, and without it we could not achieve the synthesis or creation of new compounds, such as "606", and a host of other therapeutic substances. It may make all the difference in the world — that a compound is built up on a left-handed rather than a right-handed plan; and once we realize that our chemical processes are a series of fermentations, and that a ferment may

ments are produced in the body and by the vital activities of a living thing. Fermentation, then, may be due — perhaps is always due in nature — to the growth and life and chemical activity of microbes. It is not the air that causes fermentation, though the process may be arrested in materials from which air is excluded. The exposure to air is really exposure to microbic infection, and the fermentation follows. Or, if air be necessary for fermentation, it is because air is necessary for the growth of most microbes, but it is the microbes, and not the air, that are really responsible.

To the great alarm of his teachers, Pasteur turned at once from the orthodox paths of chemistry, and devoted himself to further investigation of the ways of microbes. It seemed by no means certain that these microscopic objects really existed



MICROBES THAT BEFRIEND MAN BY PROCESSES INVISIBLE TO HIS EYE

The small microbes at the top of the first circle make milk sour, those below them help in the making of butter and cream. In the second circle are the yeast organisms, which make alcohol; in the third circle are the microbes that make vinegar, and in the last those that make cheese.

destroy a right-handed compound and yet leave its mirror-image untouched, as Pasteur showed, we begin to see light upon many of the problems of disease.

The fundamental fact discovered by Pasteur was, of course, the presence of a living agent in this fermentation. Liebig believed that fermentation was a chemical phenomenon, but Pasteur's work showed that it was a vital phenomenon — a living agent was involved. Nowadays, we see that, in a sense, any opposition between these two views was unreal, for we can often extract a chemical ferment, not itself alive, from the bodies of microbes, and can prove that this ferment does its work in the absence of actual life. Thus, the vital theory of fermentation, as upheld by Pasteur, does not really exclude the chemical theory upheld by Liebig. But the cardinal fact remains that these fer-

or mattered, if they did; and, in any case what possible fruit could be expected from the study of them? But Pasteur held on his way. He showed that, while all microbes, like all living things, require oxygen for the purpose of respiration, some obtain it from the air, whereas others cannot live in the presence of air, but obtain their oxygen for respiration by splitting up compounds containing it found in their food. The air-needing microbes he called "aërobic", and the others "anaërobic". The former will grow most abundantly upon the surface of any culture-medium, whereas the latter will grow only in the absence of oxygen and, therefore, only at some distance beneath the surface. A typical instance of the anaërobic bacteria — discovered long afterwards — is the bacillus of tetanus, or lockjaw, which grows in the soil and may thus infect any

chance wound in the hand of a gardener, without relevance to whether or not the wound be in the space between the thumb and first finger, or be made by a rusty nail, as is popularly supposed. But the great majority of wounds infected with soil fail to give rise to tetanus, because the microbe can flourish only in wounds from which the free oxygen of the air has been excluded.

Pasteur soon showed that the change in the optical activity of tartaric acid did not stand alone in being due to microbes. He found that the production of lactic acid, from lactose or sugar of milk, is also due

suggest the kind of work to which the latter part of Pasteur's life was to be devoted, for more important things than wine are subject to disease.

But first there was a very much discussed problem to which Pasteur's attention was directed and which is certainly a biological problem. This was the question of the origin of life, which we discussed in the second chapter of this section. Here we shall distinguish between the conclusions which were drawn from Pasteur's work, and the work itself. All we are entitled to say is that Pasteur's experiments refuted



THE EXAMINATION OF A CULTURE OF MICROBES IN A TEST TUBE

to fermentation by a microbe, the *bacillus lacticus*. He showed, also, that the formation of butyric acid in rancid butter is due to certain bacteria, mostly anaërobic. He found the same form in the very important case of acetic acid, which is produced from ethyl alcohol by the action of the *bacillus aceticus*. This was a matter of great practical value. By his study of these processes, occurring in wine and vinegar, he was able to formulate very useful rules for the making of vinegar, and also to give effective directions for the prevention of "wine disease". This last phrase begins to

the supposed proofs of spontaneous generation which many accepted at that time. Materials which had been deprived of life — or sterilized, as we now say — were found to remain as they were indefinitely, provided that no life from outside had access to them. They did not ferment, and no life appeared in them, no matter how suitable for the composition or generation of living beings they might be. Hence it followed, and still follows, that if spontaneous generation of life can occur or does occur at the present time, the conditions under which it does so are still unknown.

Not the least useful result of this controversy was the occasion it provided for a great many observations on the vital conditions of microbes. Only by experiment can we ascertain what temperatures microbes will survive or succumb to, and what chemical substances, in what proportions, will arrest their growth, and so act as preservatives of fermentable materials, or, to use the modern term, as antiseptics. It was in the course of this work that Pasteur discovered the method of sterilizing milk, known as "pasteurization", which consists in the prolonged use of a less degree of heat than will be effective if used for only a short time.

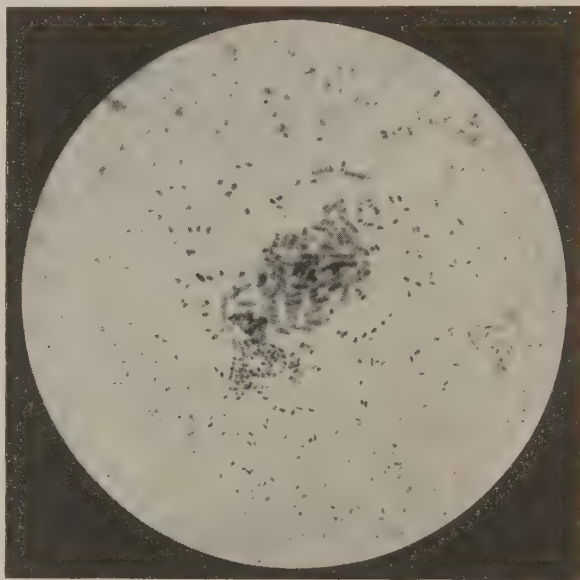
In the 'sixties, after his study of the silkworm disease, by which he was enabled to save one of the most important of French industries, Pasteur began to find that certain microbes are not merely saprophytic but parasitic, living within the tissues of other living creatures, and producing disease. Fowl-cholera matters little to us, but his work upon the anthrax bacillus, which produces the

disease anthrax not only in certain lower animals but also in man, was truly epoch-making, for this was the first demonstration of a microbe as the cause of a human disease. Needless to say, the word "cause" has a very definite meaning. Many have asserted, and perhaps some may still survive who assert, that the presence of these microbes of various kinds in various diseases is only an accompaniment or concomitant, but not a cause. It might be that the microbe, though certainly parasitic, did not really do any harm, but was merely enabled to grow in the tissues of the host in consequence of the change

produced in them by the disease. This would conceivably account for the presence of special types in constant association with special forms of disease — in each case the patient's body, on this theory, is made a suitable soil for the growth of some particular microbe. At the stage when the existence of microbes can no longer be denied, and when they are found to be definitely associated with certain diseases this explanation may be advanced.

If it be true, of course it reduces the presence of the microbes to an accident of no importance, and the real cause of the disease remains to be discovered in each case. The criticism thus advanced is

highly necessary and salutary, for there are many instances where certain forms of microbes seem to be found, perhaps constantly, in association with certain forms of disease, and have been put down as their causes, though the probability is that their presence is secondary and of no importance. This is probably true, for instance, of various microbes which have been described at vari-



BACILLI OF ANTHRAX FORMING SPORES

ous times as the causes of malignant growth.

Therefore, when we say that Pasteur found microbes to be the causes of disease, in many instances we require to cite the necessary evidence, which has always been complied with in those cases, such as anthrax, where science now accepts the evidence. First, there must be no case of the disease in the absence of the alleged cause; the association between the symptoms and what is asserted to be the causative parasite must be absolutely constant. The parasite may be quiescent or inert, or its poisons may be so neutralized by the body that the symptoms do not appear.

But if the parasite causes the disease, it must always be found when the disease is present. Constant association is thus a necessity for the proof, but it is not enough, for it proves nothing as to causation. The presence of the parasite, as we have seen, may be the effect and not the cause of the disease. It is necessary, therefore, to show that the parasite, when introduced into a normal, healthy animal, produces the disease in it. This experiment may fail, for the animal may be immune, and no symptoms follow. But if the parasite is really the cause of the disease, it will be found to produce the characteristic symptoms, at any rate sometimes, when introduced into the tissues of other individuals of the same species as that to which the first victim belongs. We should now be able to recover the parasite from the body of the second victim, and to show that it has multiplied therein, while producing the symptoms we have observed.

This may seem sufficient, but even now we have not absolutely proved that the parasite is the cause of the disease. In transferring it from the sick to the sound we are, of course, unable to isolate it in such a fashion that no fluid accompanies it. Hence, it may be argued that the parasite, thus transferred — we say parasite for convenience, but the number would probably be millions — was not the cause of the symptoms in the second victim, but that they were produced by the really efficient agency of some special poison in the fluid which was taken from the first victim, and which happened also to convey the parasite.

That was a theory which required consideration in the past, and must be mentioned now, but it is negatived by innumerable facts which have been ascertained during the past half-century. In fact, we shall see that Pasteur's next research was in itself sufficient to show that the parasite, in such a case as anthrax, is really the cause of the disease.

Meanwhile, we are to observe the nature of the evidence which science must always require before we can say that a given parasite is the cause of a given disease.

First, we repeat, the parasite must be found in all cases of the disease. This may be no easy matter, for by no means all bacilli are as large and readily detected as that of anthrax. In some forms of tuberculosis, for instance, the bacillus of that disease cannot be found, though material from the diseased parts will transfer the disease. Here the probable reason is that the bacilli have assumed an involution form or are present in such small numbers that they

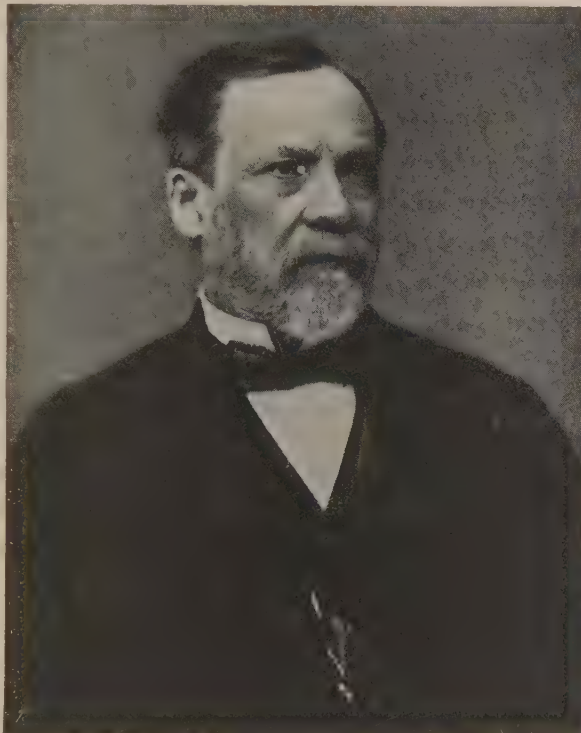


Photo Pierre Petit

LOUIS PASTEUR

escape observation in spite of our skill and care in searching for them. Second, we must not be disconcerted if we find pathogenic, or disease-producing, microbes in cases where no disease is being produced by them. At an early stage in our knowledge, such observations would have been most disconcerting. If it has been laid down that a certain coccus causes pneumonia, and a certain bacillus causes diphtheria, what are we to say when these organisms are found in the throats of persons who are in perfect health?

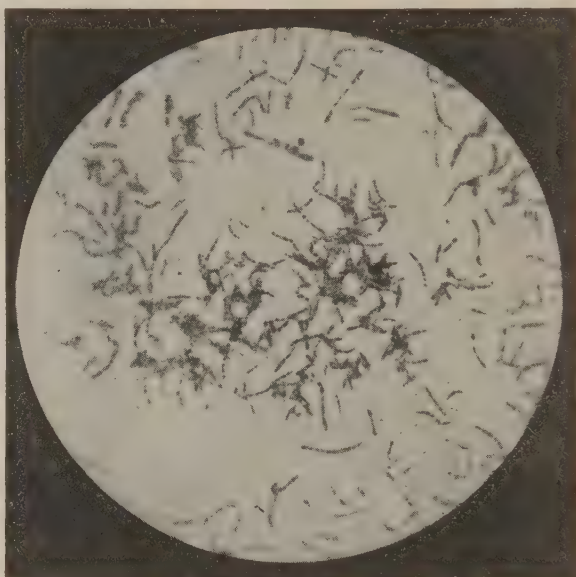
The answer, we now know, is that the accepted use of the words "pathogenic" and "non-pathogenic", as if microbes could thus absolutely be distinguished, is erroneous. We have clear evidence, for instance, that certain "pathogenic" microbes, such as those we have mentioned, may exist in the body and not be pathogenic. We are certain, also, that microbes commonly reckoned non-pathogenic may sometimes take on pathogenic action. This complicates our argument, but does not invalidate it. The fact is that microbes may behave in different ways at different times, according to the conditions of their nurture, as we shall see. Further, the soil must be reckoned with.

We now know that, for instance, there are people called "typhoid-carriers", who constantly harbor the typhoid bacillus within them. But for some personal reason they do not suffer from typhoid fever. They are in perfect health; and we might argue, as used so often to be argued, that the case against the so-called typhoid bacillus, as the cause of typhoid fever, therefore breaks down. But unfortunately the fact is that if these bacilli, from such a typhoid-carrier, get a chance of invading someone else they promptly set up typhoid fever. If such a typhoid-carrier happens to be a cook, her life-history may involve a long train of hitherto incomprehensible deaths on the part of those for whom she has worked; and only very lately has the strange but simple explanation been worked out.

These and many other instances are teaching modern bacteriologists that the supposed distinction between pathogenic and non-pathogenic bacteria must either

be abandoned or recognized in a new way. These terms are purely relative to the circumstances. A man may harbor pneumo-cocci in his throat for weeks without hurt, and then lie drunk on the road all night, and next day he will be starting with pneumonia. The cold and the alcohol have lowered his resistance — whatever that means in terms of exact chemistry — in such a fashion that the formerly innocuous cocci initiate a deadly disease. Henceforth, then, we shall try to realize that the problem of disease production is a complicated one, with many factors, and it cannot be stated simply in terms of the

seed, for instance, without any reference to the soil. The seed itself, also, offers a host of problems on account of its variability in behavior. Its successive generations follow one another with extraordinary speed, sometimes as often as three times in an hour; and in the course of a short time of exposure to certain conditions, a race or strain that began in a condition of extreme virulence



THE BACILLI OF DIPHTHERIA

may be rendered quite harmless, or *vice versa*.

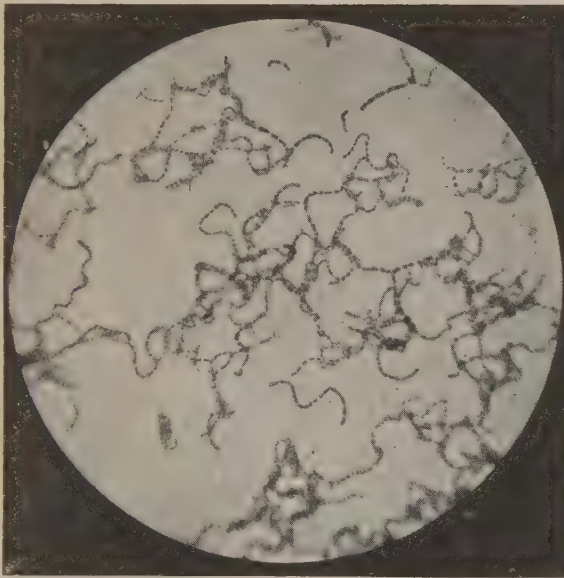
We are to understand that these parasites, unlike some of the larger animal-parasites of man, do not produce their effects by their mere presence. Their action depends upon the production of a chemical product which we may call their virus or poison. The question, then, is as to the virulence of any particular microbe, according to the abundance and quality of the virus it produces.

This requires very close study, and it is not enough to judge by effects, for those effects introduce a new factor — the resistance of the new host. Thus a given culture, of a given virulence, whatever that may be, will kill one host in a few hours, and will produce

no symptoms at all in a second. Are we to judge of the virulence of this culture by the first experiment or by the second? The fact is that the first host was susceptible; and the second, perhaps having lately recovered from an attack of the same kind, was, for the time being, at any rate, immune. We have to distinguish, then, between results which are due to changes in the seed, and those which are due to the varying conditions of the soil.

When we do so, we find that the microbes themselves can be caused to vary widely in virulence, so that they can no longer do any harm to creatures which would otherwise certainly have succumbed. Pasteur himself was the pioneer in these researches, which have already produced tremendous results for the benefit of man and of animals. He had no sooner begun his observations on the anthrax bacillus than he proceeded to study the effect upon it of many agencies. This, of course, is work of a kind which can never be finished, for there is no end to the experiments that can be made as to the action of, say, sunlight, radium, Röntgen rays, new drugs, etc., upon all manner of microbes. Pasteur soon found that the virulence of microbes is modified by exposure to air, by the conditions of their nutriment, by varying temperature, etc. Thus if anthrax bacilli be grown at a high temperature for twenty-four days they lose their virulence, and can no longer kill a sheep. This was the basis of Pasteur's method of immunizing animals against anthrax. He injected these attenuated bacilli, as they are called, into a sheep, and in this way such a resistance was somehow acquired by the animal that, when it was

inoculated, a fortnight later, with a culture which had been exposed to heat for only twelve days, and was therefore only half as attenuated presumably as the first, the animal did not suffer. A fortnight later an injection of the ordinary virulent, unattenuated bacilli produced no bad results. The animal had been rendered immune by a gradual process of cell-education, which was made possible by the discovery of a method of attenuating the bacilli by means of heat. This method is applicable also to cattle and horses, and has now been in use for many years, having enormously reduced the mortality from anthrax.



THE MICROBES OF ERYSIPELAS

But there is a more interesting and significant way in which the virulence of microbes can be attenuated. Just as growth at something well above what is called its *optimum* temperature will weaken a microbe, so growth in the body of an animal of one species will commonly weaken or attenuate it, so far as animals of other species are concerned. The

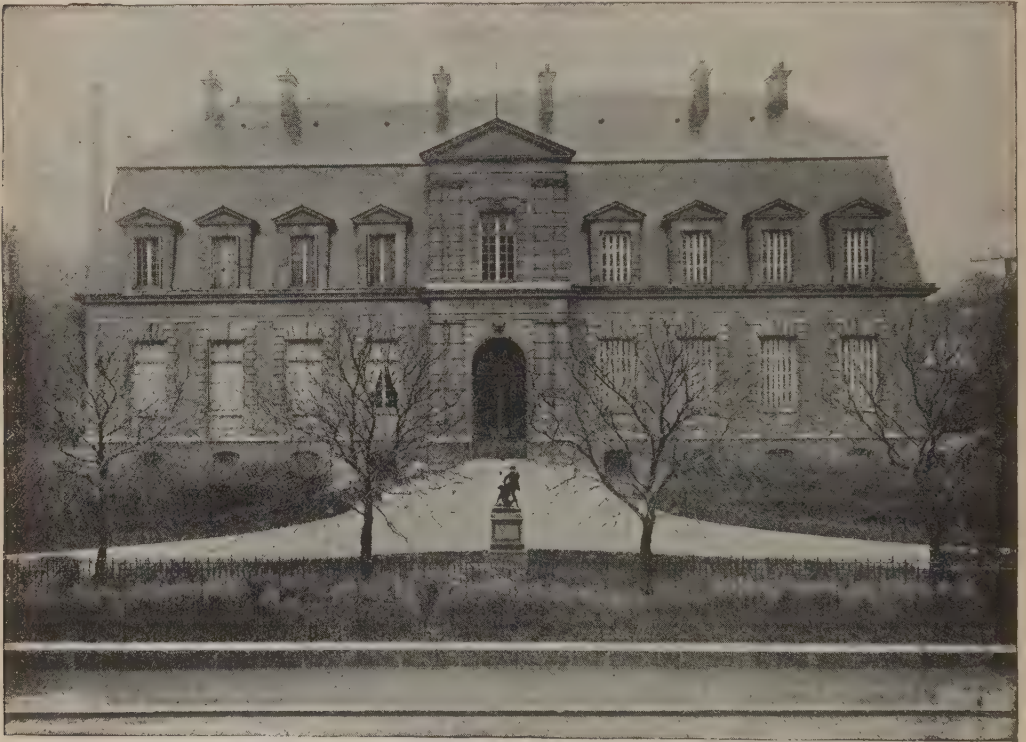
rule seems to be that the microbe adapts itself to the special conditions, and thus loses its suitability for other conditions. Thus Pasteur found that the parasite of swine-plague, when inoculated from rabbit to rabbit, increased in virulence for rabbits, but was attenuated for pigs. Organisms which had been passed through a series of rabbits produced in the pig illness, but not death; and after this illness the pig remained immune to parasites of ordinary virulence for at least a year.

Pasteur's observations led to the discovery of the general principle that the virulence of a parasite for one species is diminished by its growth in another; and that thus vaccines may be obtained which

will induce a mild attack of illness in a member of the other species, *such as will protect that individual*. The reason why we call such substances "vaccines" is evident. Clearly this process, invented by Pasteur with certain parasites he could identify, is the same as that invented long before his day by Edward Jenner, for the case of smallpox, the parasite of which is still unknown. No modern student of disease doubts that what we call smallpox in ourselves, and what we call vaccinia in the cow, are one and the same disease

oculation from mild human cases. Many deaths resulted, but the survivors were usually immune for life. Vaccination, properly carried out, causes no deaths, and does not produce such long-maintained immunity; and it acts by the method of inducing a mild attack by parasites attenuated by growth in another species — the method which Pasteur was the first to elucidate.

Just as the virulence of microbes can be attenuated, by such various means as we have mentioned, so also it can be exalted.



THE PASTEUR INSTITUTE IN PARIS WITH THE STATUE OF ITS FIRST HYDROPHOBIA PATIENT

produced by the same parasite in both cases. But the growth of this parasite in the bovine species attenuates its virulence so far as we are concerned, and thus, when we are vaccinated, we suffer from so mild a form of smallpox that it cannot even be called smallpox, but it will protect us from that disease for years.

Lady Mary Wortley Montagu in 1718 introduced into England from the East — her husband was British ambassador at Constantinople — the practice of inoculation for smallpox. This meant actual in-

This is most easily done by the method of *passage* discovered by Pasteur, and illustrated in the case of swine-fever and rabbits. As the organism is passed on from one susceptible animal to another, it increases in virulence, and this explains the fact, often observed, that epidemics increase in deadliness as they advance, for the later victims of the infection are attacked by parasites whose virulence is exalted by passage through the earlier patients. It has also been found that the virulence of a parasite is usually increased

when some other parasite, or its poison, is injected at the same time. The resistance of the host is reduced, and the parasite can thus grow freely and increase in virulence. This is an observation of extreme importance in all forms of tuberculosis, where septic surgery, neglect and exposure to foul atmospheres and dust are very liable to introduce other infections, which most

1885, after a long series of most complicated researches, calling for every great scientific quality of mind. At last, by following the principles already mentioned, he was able to provide himself with preparations which contained the virus of hydrophobia in what may be called its normal strength, and in forms attenuated and exalted. These were contained in the nervous



THE TOMB OF LOUIS PASTEUR IN THE CHAPEL IN THE PASTEUR INSTITUTE, PARIS

gravely complicate the case — largely, as we may now guess, because the virulence of the bacillus of tuberculosis is enhanced under such conditions.

At least as famous as any other research of Pasteur's, though not so far-reaching in its consequences, is his work upon hydrophobia, or rabies, a disease of which the nature of the causal parasite is still undetermined. His results were published in

tissues, brain and spinal cord of animals of various kinds, for Pasteur found that the virus is always most abundant in nervous tissues. With these preparations Pasteur sought to act on human beings who had been bitten by mad dogs, availing himself of the comparatively long period of incubation in man, which is usually about forty days, but may be very much longer.

The first case treated was that of a young shepherd boy who had been bitten by a wolf; and his statue, representing him in the act of trying to defend himself from the animal, now stands outside the Pasteur Institute in Paris. This patient received a series of injections, from the spinal cords of rabbits, each successively being made from a cord of greater and greater virulence. Immunity was thus induced, and the dreadful symptoms of hydrophobia never appeared.

been similarly obtained by Pasteur Institutes in many parts of the world — other parts of France, Italy, Russia and America. In Paris those who have carried on Pasteur's work have attained such perfection that the mortality, which was less than 5 per cent in the ten years preceding his death, has been reduced to practically nothing, with the sole exception of a few persons suffering from chronic alcoholism, in whom the process of immunization has been impossible of attainment.



THE STATUARY GROUP OUTSIDE THE PASTEUR INSTITUTE IN PARIS, SHOWING THE ATTACK OF A WOLF ON THE SHEPHERD BOY, JUPILLE, WHO WAS THE FIRST PATIENT FOR HYDROPHOBIA

It is, of course, a legitimate and necessary objection to the claims made for this method that the patient may not have been infected in the first place. Thus the Pasteur Institute does well to estimate its results only in terms of patients bitten by dogs proved to have had rabies by inoculation of healthy animals with parts of their nervous system. In the year Pasteur died 122 cases of this class were so treated, without a death. The ordinary mortality was 16 per cent of persons bitten, and this percentage would include a good many bitten by dogs not really mad. The results have steadily improved, and have

Such, in very brief outline, is the life work of Louis Pasteur, but centuries must pass before all its fruits can be told. Of all physical benefactors of mankind, since the dawn of time, this man is supreme — the founder of bacteriology and the father of preventive medicine. "It is in the power of man," he said, "to make all parasitic diseases disappear from the earth." He was a devout Catholic, and was fond of saying "Tout est miracle", a remark worth recollecting by those who think that science has made all things plain because they have lately learned a fraction of what Pasteur discovered.

OUR COMMON BIRDS VI

The Beneficial and Destructive Hawks,
Soaring Eagles and Malignant Owls

THE BIRDS OF PREY

NATURE does not intend her children to lead easy lives. As soon as life becomes easy, progress ceases and decay sets in. There must be constant struggle and competition, and only the best and strongest must live to perpetuate their kind. She has little time to waste on the weak or the lazy; the sooner they are out of the way, the better for the rest. So nature has provided obstacles which every organism must surmount to reach maturity, and enemies to its adult life which require constant alertness and courage to escape. She provides every organism with a capacity for reproduction in proportion to the number of obstacles or enemies which it has to surmount, so that, though many may fall by the wayside, the most virile and progressive individuals will be left to continue the race. Wherever nature exists unmodified by man, we find a balance of these two great forces, that of reproduction and that of destruction, and all organisms maintain the same relative abundance year in and year out so long as the environment remains the same.

A single protozoön in a jar of water will in a few days cause the entire jar to appear milky with its thousands of offspring in order that at least one of its children may reach maturity and be carried to some other suitable environment. A soft-bodied, helpless plant louse reproduces at the rate of over ten sextillion a year for the same reason, and the oak tree showers its acorns on the ground every year that at least one may be carried to fertile ground, surmount the obstacles of browsing animals and defoliating insects and at last bear acorns of its own.

The protozoön, or the plant louse or the oak tree that finally reaches its maturity is the pick of thousands and has all the vitality of its parents and usually a little bit more. For it is thus that nature progresses and thus that the most complicated organisms have evolved from the lower and more simple.

And so we find whole groups of organisms intended by nature to cull out the weaker individuals of other species and thus assist the process of evolution. Among animals it is the carnivores, the tigers, the wolves, the bears, the weasels and their kin. Among birds it is the birds of prey, the hawks and the owls, that perform this necessary function of insuring the strength of the different species of birds.

Of course man does not feel the need of this method of maintaining the strength of his domestic fowls and rues the slightest pillaging of his poultry yard or game covers. Fortunately, there are few species that indulge freely in this thievery and the majority more than make up for it in their destruction of harmful rodents, for the food of hawks is composed even more of rodents than of birds.

There are nearly 500 different kinds of hawks, found in all parts of the world. Many species resemble each other very closely, others have diverged widely, but all can be recognized by their short hooked bills, their strong talons and the absence of the facial disc which characterizes the owls. Parrots, which are somewhat hawklike in appearance, have very thick bills and have two toes directed forward and two backward instead of three in front and one behind.

Hawks vary in size from the gigantic condor and the California vulture which measure over 12 feet from the tip to tip of the wings, to the pygmy falcons of India which are scarcely larger than a sparrow. The females are usually larger than the males, frequently exceeding them by several inches in length. Thus the male Cooper's hawk measures but a little over 15 inches in length while the female averages 19 inches.

Most species are inconspicuously marked with brown and gray, but some have quite striking patterns of blue and reddish brown. With some species, like the marsh hawk, the male and female are different, but usually the adults are colored alike and the immature are different. The adults tend to become very gray above and barred below while the immatures are brownish above and streaked rather than barred below. The color patterns of many species are so similar that it is much easier to distinguish them by their size or their shape than by their color. Thus the red-tailed, red-shouldered, broad-winged and rough-legged hawks all have large rounded wings and broad fanlike tails; the goshawk, Cooper's and sharp-shinned hawks have short rounded wings and narrow tails; the marsh hawk and the fish hawk have long narrow wings, and the falcons have very pointed wings. Each type is adapted for a particular feeding habit: the large-winged species circle high overhead on the watch for their prey and their wings and tails are therefore adapted for soaring; the short-winged hawks lie in wait for their prey in the shelter of the foliage and their wings are adapted to sudden bursts of speed from a stationary position; the long narrow-winged hawks beat back and forth over the meadow or the water and are on the wing for long periods of time, and their wings are adapted for sailing and long continued flights. The falcons pursue their prey and strike in full flight and, therefore, have pointed wings adapted for great speed.

All hawks are carnivorous, but the diet of some species consists largely of insects, snails, frogs, snakes, lizards or fish and some are scavengers and feed upon decaying animal matter. Their value in controlling small rodents can scarcely be overestimated.

The eyesight of hawks is extremely keen and the power of focal adjustment is wonderful. From hundreds of feet overhead, they scan the ground and are able to see the tiniest mouse or lizard. In the instant required for them to drop from that height and pounce upon their victims, their eyes change from long to short focus, and the adjustment is so instantaneous that they follow their prey with clear vision. The eyes of hawks are smaller than those of the owls, for all the species are diurnal, although some species, like the rough-legged, are most active toward dusk, and the tropical laughing falcons can be heard long after dark. Hawks' eyes vary in color from yellow to ruby-red, some being gray and others brown. Young birds usually have different colored eyes from the adults, those of the Cooper's hawk, for example, changing from gray to yellow to bright red. In some species the eyes of the females are different from those of the male. Female marsh hawks, for example, have brown eyes while those of the males are yellow.

The voices of hawks, for the most part, are harsh, discordant screams, quite in keeping with their wild natures. The short-winged species, like the sharp-shinned and Cooper's hawks, that lie in wait for their prey, are usually silent, except on their nesting grounds, but the others call frequently as though to strike fear in their quarry.

There are four families of hawks found in North America, but, with the exception of the vultures, they may well be considered together. The family *Buteonidæ* includes the majority of hawks and are variously known as the broad-winged hawks, also called buzzards in Europe, kites, harriers, eagles, goshawks, etc. The family *Falconidæ* includes the falcons and the caracaras, the latter being degenerate falcons which have become largely vulturine in their habits. The family *Pandionidæ* includes only the fish hawks or ospreys, which differ from other hawks in that one toe is reversible so that a better fish gaff is formed by having two toes directed forward and two backward. The family of vultures, *Cathartidæ*, are degenerate hawks having naked heads and weak feet, and feed almost entirely upon carrion.

The vultures

There are nine species of the family *Cathartidae*, confined entirely to the New World. The Old World vultures, although very similar in general appearance, are put in a different family. In North America there are but three species and one of these, the California vulture, is nearing extinction because of the poisoning of carcasses by rangers to kill wolves and coyotes. This is one of the largest and most majestic birds of flight in the world, some individuals measuring eleven feet from tip to tip of the wings. Every effort should be made to save the remnant that still may be found in remote portions of the California mountains. The other two species, the turkey and black vultures or "buzzards", as they are sometimes called, are very common in southern United States and occur as far north as New York and New England. The turkey vulture is the larger of the two and can be distinguished by its red head and longer wings

and tail. The black vulture, having shorter wings, does not soar so continuously but flaps its wings more frequently while flying. The black vulture is more tropical and is seldom seen north of Virginia or Indiana. Both the turkey and black vultures have uniformly black plumage and naked heads and have the habit of soaring high on steady pinions, often rising far above the clouds without any apparent motion of the wings. Again in the same manner without a wing beat they will set their flight in one direction and disappear from sight. One of the most remarkable phenomena in connection with the vultures is the rapidity with which a flock will assemble about a dead animal, for in addition to scanning the ground, vul-

tures keep keen watch on each other and when one indicates, by a change in its flight, that it has discovered something, all the others that have been watching it for miles around flock to the spot. Their vision is extraordinary, for the smallest dead snake or mouse does not escape detection by birds several hundred feet up in the air. It was at one time believed that their eyes were assisted by a very keen sense of smell, but it has been shown that if a strong smelling carcass is entirely concealed, the vultures do not discover it.

The value of vultures as scavengers was never questioned until recent years when it was supposed that they might assist in the spread of anthrax among cattle, and in some

states the laws that had always given them protection were repealed. Few persons, however, bear the vultures any grudge and they will probably thrive even without the protection of the law. In most places they seem to recognize the good will of mankind and are not in the least timid, particularly the



OLD WORLD VULTURE
Griffon Vulture



NEW WORLD VULTURE
Turkey Vulture

black vultures, which in the streets and markets of some southern cities form a regular part of the street-cleaning service. In parts of South America they are likewise employed to clean the hides of cattle of all flesh and fat. The hides are stretched on large frames and set out where the vultures are waiting, and the hand scraping, which is usually a tedious process, is found entirely unnecessary.

Except during the nesting season, vultures usually resort to a common roosting place toward which they can be seen sailing after sunset. Another common sight is to see them in early morning or after showers perched on the gables with spread wings drying their feathers.

Vultures lay their spotted eggs either on the ground under a log, in a hollow log or cave, or sometimes high up in a hollow tree. The young are covered with whitish down and are helpless for a long time. In fact, the South American condor, which is the largest of the family, is said to feed its young on the nesting ledge for nearly a year before they are able to soar like their parents. This is because their wings are so large and heavy that it takes great strength to manipulate them. Even the adult birds have difficulty in getting under way from level ground, particularly after gorging themselves upon carcasses. At such times they are often captured and before the importation of their plumes into the United States was prohibited, they were nearly exterminated over a good part of their range.

The true hawks

The majority of the true hawks belong to the family *Buteonidae* and are variously known as kites, eagles, harriers, buzzards or hen hawks, goshawks and sparrow hawks or chicken hawks. The terms "buzzard" and "sparrow hawk" are both confusing because in America the former is used synonymously with vulture and the latter is applied to the smallest of the falcons. In Europe, however, the broad-winged, fan-tailed hawks are called buzzards and the short-winged, long-tailed hawks sparrow hawks.

Without reference to family divisions, there are four types of hawks according to the shape of their wings and tails and their corresponding food habits, and they may well be considered from this point of view.



HEAD OF A CAPTIVE RED-TAILED HAWK
The so-called "hen hawk."

The group of broad-winged, fan-tailed hawks includes the red-shouldered, red-tailed, broad-winged, Harris', Swainsons' rough-legged, and a few other hawks, and the bald and golden eagles. With their extended wings and spread tails, they circle high overhead as do the vultures, though, with the exception of the eagles, they are much smaller. In general, they live in wooded districts but do most of their hunting about open fields. They are all commonly spoken of as "hen hawks" and are supposed to be poultry thieves, but, in fact, the group feeds principally upon small rodents and the larger insects. The broad-winged and rough-legged hawks have practically a spotless record and the red-shouldered and red-tailed only rarely offend.



NEST AND EGGS OF RED-SHOULDERED HAWK



YOUNG RED-SHOULDERED HAWKS IN THEIR NEST

The photographs on this and succeeding pages of this chapter, except that indicated, are by A. A. Allen.

The members of this group of hawks are most usually seen soaring overhead and are best identified by the pattern of dark marking on their underparts. Thus the broad-winged hawk has the under surface of the wings pure white with the exception of the dark tip formed by the dark first primaries. The red-shouldered hawk has the under surface of the wings barred but with no distinct black patch; the red-tailed has a distinct crescentic black mark at the "wrist" which in the rough-legged hawk is very large and conspicuous.

The eagles are usually recognizable by their large size. The bald eagle was chosen as our national bird more because of its majestic appearance than because of its habits, for it feeds principally upon fish cast up by the waves or those which it steals from the osprey. Occasionally it takes crippled water-fowl. The adult birds have



OUR NATIONAL BIRD

Adult bald eagle. It takes four years to develop the pure white head and tail.

the white head and tail always illustrated, but the immatures have the head and tail brown like the back, and require several years to come into adult plumage. In fact, they are very similar to the golden eagle except in the feathering of the legs, the bald eagle having the lower tarsus bare while the golden eagle has the legs feathered all the way to the toes.

The golden eagle is very rare east of the Mississippi River, being most abundant in the mountainous parts of the West.

It is a much more active bird than the bald eagle and preys upon rabbits, grouse, young lambs and fawns. The stories told about its carrying off young children are highly improbable since it has been shown that the greatest weight it can carry is six pounds. Like the bald eagle, it sometimes builds a bulky nest of sticks in the top of a tall tree, but more often it nests on ledges of inaccessible cliffs. In fact, all of these broad-winged hawks build very similar nests of sticks and lay similar spotted eggs.

The short-winged hawks include the sharp-shinned, Cooper's and goshawks. They seldom soar and when they do, it is in very narrow circles. Usually the habit of these hawks is to choose some inconspicuous perch and remain perfectly quiet until the disturbance which its arrival caused among the birds subsides. Then when the birds have forgotten its presence it dashes from its perch, usually with successful aim, but sometimes it misses and, still determined, may follow the victim on



IMMATURE BALD EAGLES (CAPTIVE BIRDS)

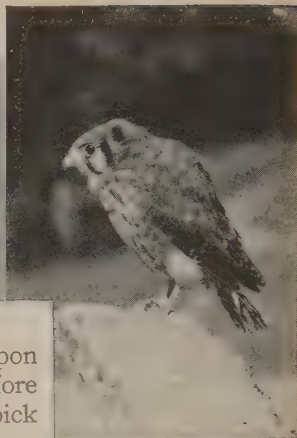
foot through the brush. Again, flying low through the woods or open country it will make a sudden dash into a flock of birds without any preliminary waiting, and at such times it is very bold and may strike birds within a few feet of one. These hawks



SPARROW HAWK AT ITS
NESTING HOLE



YOUNG SPARROW HAWKS, ONE IN AN
ATTITUDE OF DEFENSE



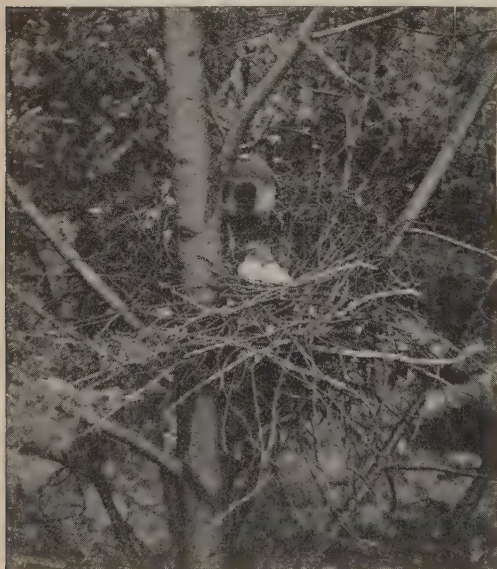
YOUNG SPARROW HAWK
WAITING FOR DINNER

have been known even to pounce upon game birds that have just been shot before the surprised hunter has a chance to pick them up. During a recent summer, on two occasions, a sharp-shinned hawk attacked birds within twenty feet of the writer, and

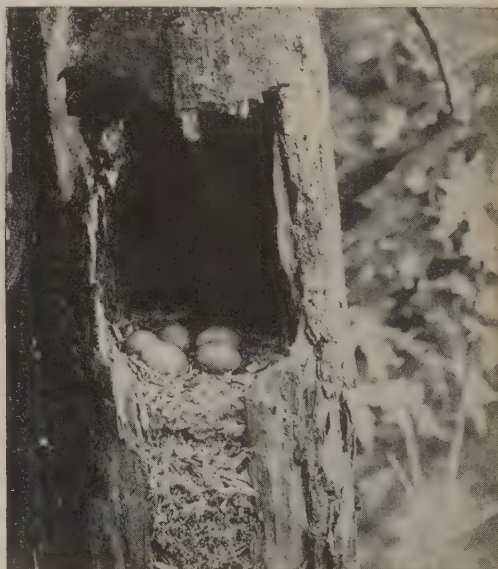
another time flew into an open window of the house, after making an unsuccessful dash at some birds at the feeding station.

These three hawks are the great bird destroyers which have brought the whole family into disrepute by their thefts in the poultry yard. The sharp-shinned hawk, because of its small size, usually confines its attention to the young chickens, but the Cooper's hawk may attack anything up to full-grown hens. The goshawk, which is a more northern species, coming southward

into the northern United States in winter, is the most destructive of all, and when it comes in big flights, as it does about every ten years, when the rabbit supply in the north fails, it is a great menace. The adult goshawk differs from the other two species in the color of its underparts, these being gray, penciled with narrow black lines. The adults of all three species are dark slaty gray above and the Cooper's and sharp-shinned hawks have the underparts barred with rusty brown. The immature birds of



COOPER'S HAWK AT ITS NEST IN A TALL
HEMLOCK



NEST OF A SPARROW HAWK IN A CAVITY IN A
DEAD TREE

In the right-hand picture the side of the tree has been removed to show the eggs. The natural entrance was above and on the opposite side of the tree.

all three species are brown above and white below, streaked with brown. The females are so much larger than the males that a female sharp-shinned is nearly as large as a male Cooper's so that the only safe way to distinguish the two species is by the shape of the tail, which is square in the sharp-shinned and rounded in the Cooper's hawk.

The falcons are perhaps the most striking and interesting of all the hawks. Although not of the large size, they are the most powerful and, with the exception of the sparrow hawk, strike their victims in full flight. The gyrfalcons, of the Far North, are the largest, measuring two feet in length; the duck hawk or peregrine falcon is next and the pigeon hawk and the sparrow hawk are the smallest. It was, preëminently, members of this family that were used in the day of falconry. The taming and training of hawks for sport was quite universal in Europe by the end of the ninth century, although it had been practised in China as early as 400 B.C. The name "falcon" was ordinarily applied to the females, the smaller males being called "tiercels". In the 16th century, falconry had become so universal that everyone who could afford to do so kept a hawk, and the rank of the owner, we

are told, was indicated by the species which he kept. Thus, a king kept a gyrfalcon, a prince the falcon gentle, an earl the peregrine falcon, a lady the merlin, a young squire the hobby. A yeoman carried a goshawk, a priest a sparrow hawk, and a knave or a servant a kestrel.

The gyrfalcons are northern in their distribution and must have been brought down from the Scandinavian mountains to England or the Continent. The European species is lighter and bluer than the American. The peregrine is almost identical with our duck hawk, the merlin with our pigeon hawk. The hobby has relatively longer wings than the other falcons and has no representatives in North America. The European goshawk has a more distinctly barred breast and the European sparrow hawk corresponds to our sharp-shinned hawk, while the kestrel is very similar to the North American sparrow hawk.

Falcons nest on cliffs or in trees but seldom build nests of their own more than enough to keep the eggs from rolling. The eggs are laid either on the bare ground, in cavities of trees or in the deserted nests of crows or other hawks, and are usually so spotted as to appear uniformly brownish.

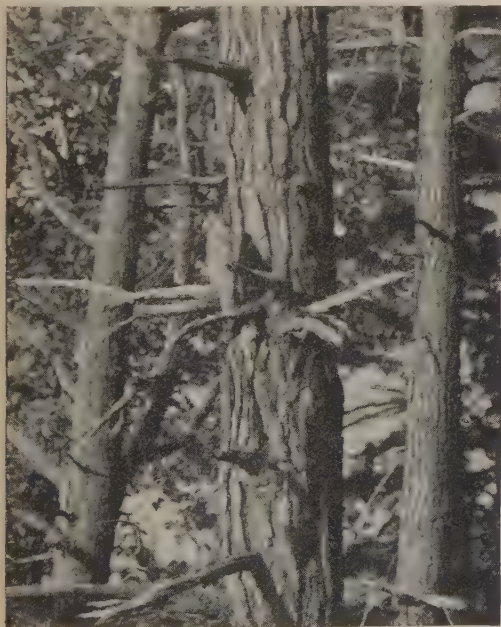


Photo H. H. Knight

IMMATURE DUCK HAWK IN A DEAD HEMLOCK

DUCK HAWK APPROACHING NESTING LEDGE

The nesting place, and four downy young, in the right-hand picture were 75 feet from the top and 200 feet from the bottom of the cliff.

The hawks having relatively the longest and narrowest wings are the kites, the marsh hawks and the fish hawks, the last belonging to a separate family, *Pandionidae*, and having quite different habits. In fact, about the only thing in common between the three is that they all remain on the wing for long periods at a time and have developed the type of wing which seems best adapted to gliding.

The kites are the lightest and most graceful of all the hawks, being almost swallow-like in their flight. Particularly is this



MARSH HAWK

About to alight on a stub overlooking the marsh and its nest.

true of the swallow-tailed kite of southern United States and tropical America, a strikingly marked white and black bird nearly two feet in length, whose swallow-like appearance is augmented by its deeply forked tail. The most beautiful and graceful sight that has ever been the writer's good fortune to behold was that of a troop of these birds skimming the water like a band of swallows, darting after one another in playful sport, rising abruptly hundreds of feet without apparent effort, diving, sailing, reversing, absolute masters of the air.

The marsh hawk is quite a different looking bird, though light of body and long of wing. It is seldom found far from the marshes, except during its migrations, although it does a great deal of feeding about open fields where mice are abundant. Occasionally it takes young ducklings or marsh birds, but most of its food consists of mice, frogs, snakes, etc. It can easily be distinguished by a white patch above the tail.

The marsh hawk nests on the ground, usually in the marshes but sometimes by stumps in upland pastures, and lays from five to seven pure white eggs. It seldom perches in trees, preferring some low perch on a fence post or on the ground. Occasionally, however, near the nest, it selects some high stub or dead tree from which it can keep a lookout. During the mating season the male performs curious evolutions in the air, sometimes turning somersaults from a considerable height toward the ground or again "looping the loop" on an angular course across the marsh.

The fish hawk or osprey is most abundant along the sea-coast but is found inland about most large bodies of water from the tropics to the Arctic Circle. With slight variations it is found all over the world. Unlike other hawks, it sometimes nests in small colonies, especially where food is abundant, and where protection is afforded. Thus on Gardiner's Island, L. I., there are about 200 of these birds nesting. It builds an enormous nest of sticks, usually on the top of a broken tree, although where protection is given them, as on Gardiner's Island, they sometimes descend to the ground.

Fish hawks are sometimes confused with bald eagles because of their great wing expanse and the large white areas on the head. Unlike the eagles, however, their underparts are white and their tails dark. They feed entirely upon fish which they locate near the surface of the water while hovering overhead and secure by plunging, often from considerable heights, and catching them with their talons. The fish taken often weigh several pounds, and there is a record of a hawk that pounced upon a fish too large for it to lift, and being unable to release its talons, it was carried beneath and drowned.



A MALE MARSH HAWK AT ITS NEST AMONG THE CAT-TAILS



YOUNG MARSH HAWKS JUST HATCHED THIS VERY DAY

As before stated, the toes are placed two in front and two behind and the soles, moreover, are armed with sharp spicules for cutting through the slime and assisting in holding the slippery, squirming prey. The fish is carried lengthwise, usually to some high perch where it can be devoured. Fish hawks are sometimes quite destructive to spawning pike and pickerel but ordinarily the surface feeding fish which it catches are of little value.

Taking the hawks as a whole they are a much maligned group, as they are much more beneficial than destructive. The whole family is usually made to pay for the sins of a few, so much so, in fact, that even today, when most people are enlightened as to their value, we still hear a cry for bounties to be placed on their heads.

No greater mistake could be made than to start a wholesale destruction of the birds of prey. There are undoubtedly areas of extensive poultry or game production where hawks are too numerous and should be thinned out, but take it the country over, they are as necessary as any group of birds.

The owls

There is something irresistible about an owl. The killing of one creates an excitement like the catching of a horse thief or the hanging of a criminal, and even the sight of a dead one draws a crowd. Never is an owl allowed to die a peaceful death, or, once dead, to return to dust in the natural way. It must be stuffed and posed on a root and two great glass eyes set in its forehead, to "ornament" some shop or home.



YOUNG SCREECH OWLS

For some people a morbid charm seems to attach to the bird, because it hides during the day and comes out at night when crimes are perpetrated. The call of an owl is a sign of approaching death, and one must be quick to turn his pockets inside out in order to save his life or that of some one dear to him. This and many other superstitions cling to the poor innocuous bird that sometimes approaches our dwellings to rid the garden of mice and rats.

There are over 300 species and sub-species of owls in the world of which only nine are found in North America, but some species occur everywhere from the Arctic to the Antarctic with the exception of a few islands. Some species, notably the short-eared owl, are nearly cosmopolitan in their distribu-

against the trunk, the more they resemble the bark or dead wood, the less likely are they to be disturbed. So we find in the woodland owls, which group includes the largest number of species, that they are mottled, streaked and barred with various shades of brown and gray. To add further to the camouflage, the heads of a number of species are adorned with tufts of feathers called horns or ears, which give the head a jagged contour and render its protective coloration the more effective. The short-eared owls that live in the marshes are yellow and more striped like the dead vegetation, the burrowing owls are rather sandy, like the soil, and the snowy owls, belonging to the frozen north, are much whiter than the average.



YOUNG SCREECH OWLS IN THEIR NESTING CAVITY



OWLS CAMOUFLAGING THEMSELVES
Screech owl mimicking a broken piece of bark.



PROTECTIVE COLORATION OF SCREECH OWL ON HEMLOCK

tion, but the majority, if not local, show such range of variation in different localities as to be separately named. Thus the great horned owls in North America are divided into eight different races and the screech owls into nine.

In size owls vary from the elf owl of our Southwest, which is not much larger than a sparrow, or about 6 inches long, to the great gray owl that measures 27 inches in length and fully 5 feet from tip to tip.

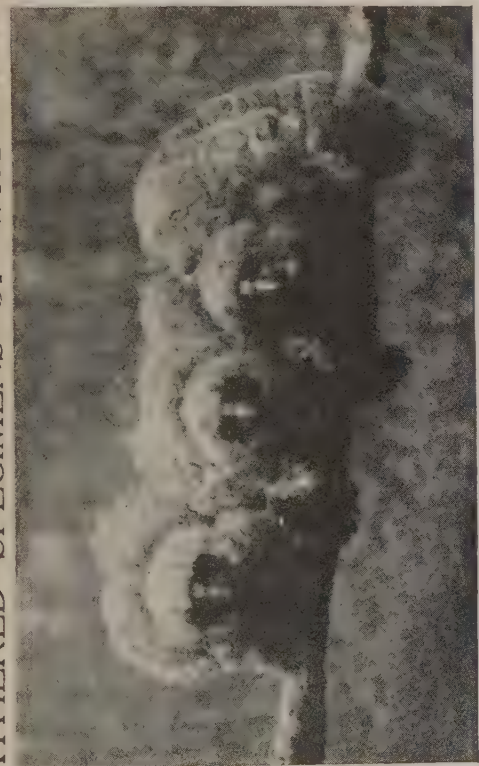
In color owls are very much alike and also in form so that no one has any difficulty in recognizing owls, as such, at sight. The predominating colors are browns and grays though some species are distinctly yellowish, others reddish brown, and the snowy owl of the Far North largely white. The reason for their similarity in color doubtless lies in the similarity of their habits. Hiding during the day in hollow trees or close up

The color is but one of the many ways in which owls are alike. All are carnivorous and have sharp talons and strongly hooked bills. In this respect they are very similar to the hawks. Indeed, until recent years, a close relationship between the two groups was thought to exist, but it is now believed by most ornithologists that the similarity has been brought about by like feeding habits and that they are in reality quite widely separated groups, the owls being more closely related to the night hawks and whip-poor-wills. Aside from numerous anatomical differences, the owls are unlike the hawks in having their eyes set immovably in their sockets and at the front of the skull so that both are directed forward. For this reason, an owl has to turn its head in the direction in which it wishes to look. Owls' eyes are unusually large so as to admit as much light as possible for night work.

SOME FEATHERED SPECIMENS OF WISDOM PERSONIFIED



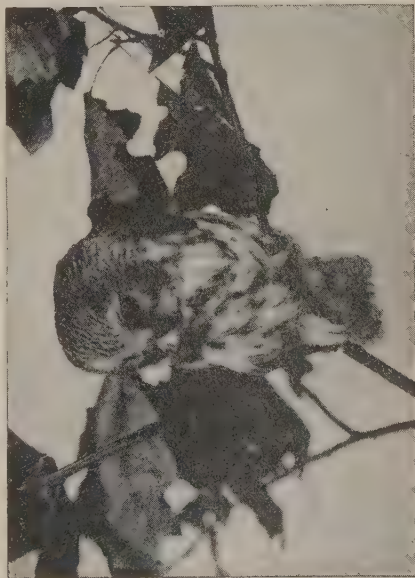
BARRED AND LONG-EARED OWLS



YOUNG LONG-EARED OWLS TRYING TO INTIMIDATE THE PHOTOGRAPHER



SNOWY OWL (CAPTIVE BIRD)



ACADIAN OR SAW-WHET OWL (CAPTIVE BIRD)



BARN OWL



SHORT-EARED OWL (CAPTIVE BIRD)

The upper left-hand photograph was taken by D. Gordon, the central lower by C. Reid, the others by A. Allen.

It is commonly believed that owls cannot see during the day. On the contrary, they can see very well, for the iris can be drawn very close until scarcely more light enters than would with the normal aperture at dusk. The belief probably originated from the tameness or stupidity of some species which permit themselves to be captured during the day. On the other hand, certain species, like the hawk owl and snowy owl, regularly hunt by day and other species, like the short-eared and great-horned owls, hunt on dark days when they have young to feed.

Owls are not dependent upon their eyes solely for hunting or escaping enemies, for their hearing is extremely acute. The discs of stiff radiating feathers about the eyes, that give owls their somewhat human expression, are for the purpose of protecting the opening of the ear. The tufts of feathers that adorn the heads of many species, and are sometimes called "ears", have nothing to do with true ears. In most birds the ears open through small apertures, covered and protected by somewhat stiffened, modified feathers, below and behind the eye. No external ear is present. With the owls, however, although the canal leading to the internal ear is not relatively much larger, there is a true external ear in the form of a fold of skin and an underlying groove which extends from above the eye, around the side of the facial disc to below the bill. The facial disc protects the front edge of the ear and several rows of somewhat curled feathers the rear edge, but so closely appressed are they normally, that one might never suspect the presence of large ears. It is probable that hearing plays a very important part in the owls' pursuit of prey.

Another peculiarity of the owls, in which they differ from all hawks except the osprey, is that their toes are normally placed so that there are two in front and two behind. The outer toe, however, is opposable and can be brought around to the front. In the majority of species, the feathers extend down the legs and toes to the talons.

The feathers of owls are extremely soft, even those of the wing, so that these birds make very little noise in flying. The In-

dian name for the owl, "hush wing", refers to this, and the silence of their flight is almost proverbial. This permits them to fly through the woods or low over the meadow without frightening the small rodents upon which they feed.

Since most small animals are nocturnal and most birds diurnal, the chief food of the owl is small mammals and the birds suffer relatively little. Extensive studies of the food of owls made by the United States Biological Survey have shown a very small percentage of birds or poultry in the food of any species, except the great-horned. They are, therefore, among the most beneficial birds that we have, for it is absolutely necessary that some check be placed upon small rodents.

Take the meadow mouse as an example. This little animal has from five to eight young in a litter and from three to six litters a year or from fifteen to fifty young annually. If the number of young each year were only fifteen and they should multiply unchecked, there would be at the end of five years, over 75,000 offspring from each pair. It is not necessary for each one of these small rodents to do much damage for the aggregate to be unbearable. The destruction which a normal number sometimes do to young fruit trees or to grain in the stack often amounts to thousands of dollars. Where unusual numbers assemble because of an abundant food supply or successful reproduction, the damage done is stupendous. In Australia, during the Great War, when it was necessary to store grain in the open or on wharves, it was so defiled by rats and mice that the loss amounted very quickly to thousands of dollars. Every year in the United States, according to estimates made by the Biological Survey, the loss due to prairie dogs, ground squirrels, pocket gophers, jack rabbits, meadow mice and pine mice amounts to over 150 million dollars. House rats and house mice account for another loss to our food supply of over 200 million, not including the loss by human disease transmitted by these pests. In these days when the maintenance and increase of the food supply is so important, the value of owls, the rodent-destroying machines, cannot be overemphasized.

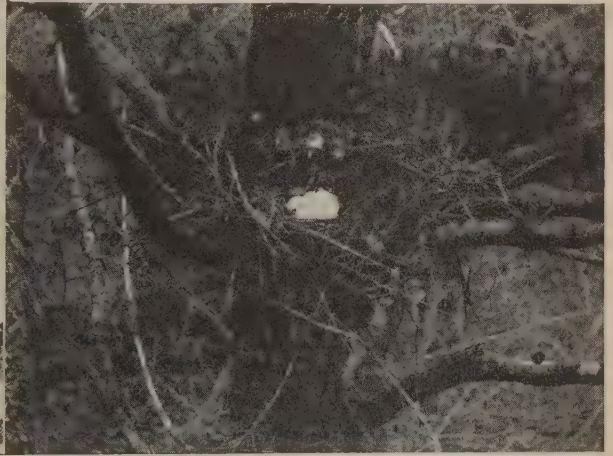
It is not difficult to prove to one's satisfaction what the local owls are feeding upon. All owls have the habit of swallowing their quarry, unless it be very large, entire, fur, bones, feathers and all. If it is very large, it is torn into a few pieces and these swallowed. The stomach digests the flesh, rolls up the bones and fur into neat oval packets and these are then disgorged in the form of pellets. Anyone familiar with the places where owls roost knows of these pellets. An examination of them, as shown in the accompanying photograph, shows how



GREAT-HORNED OWL (CAPTIVE)
With a duck.

The common prejudice against owls is due largely to superstition and to the destruction that is occasionally wrought about the poultry yard by the great-horned species. This magnificent but dangerous bird carries off full-grown hens and has been known to nip the heads from full-grown turkeys. It sometimes kills for the mere joy of killing, destroying many fowls during a single night. On poultry and game farms it is a bird to be feared and persistently trapped, but in the woods, where rabbits and mice and weasels are plentiful, it is more beneficial than destructive.

Another large owl that is often confused with the great-horned owl under the common appellation of "hoot owl" is the barred owl. It is nearly as large as the great-horned but it does not have the "horns" on the head and has none of the yellow-brown in its plumage characteristic of the latter.



GREAT-HORNED OWL'S NEST IN A TALL PINE
A rat and a pigeon in storage.

large a percentage, if not the entire food, is composed of small rodents.

The wandering movements of some owls make them the more efficient protectors of our crops, for they move from place to place, seeking abundant food. Particularly is this true of the short-eared owl, for whenever meadow mice become unusually abundant in a locality, and threaten to become a great pest, a flight of these owls usually follows. They remain in that locality, nesting if need be, until the rodents once again become scarce, and then they move on to another region.

The plumage is distinctly barred rather than mottled. The calls of both birds are hoots that can be heard for a half a mile or more. The ordinary call of the barred owl can be distinguished by its ending in a descending nasal inflection, thus:

Whoo-hoo-whoo who-whoo-to-whoo-ah
while the great-horned owl's cry would be written:

Whoo, hoo-hoo-hoo, whooo, whooo

Both species, however, have other calls that are given occasionally.

The snowy owl is somewhat larger than either of these owls and is uniformly white, lightly barred with brown. It spends the summer from central Mackenzie and Alaska northward, and in winter from the arctic shores southward, sometimes as far as northern United States or even rarely as far south as Texas and Louisiana. Its southern migrations depend largely upon the abundance of rabbits and lemmings in the North. When these fail, which is usually once in ten years, considerable numbers reach the United States.

The long-eared owl resembles the great-horned in having ear tufts, but it is much smaller and more slender and does not have the white throat patch. It is usually found in evergreen thickets during the day and, except during the nesting season, all the owls of the vicinity may resort to one such thicket to roost. Sometimes the roost is in a single thick cedar tree.

The short-eared owl is found only about grassy marshes or pastures. Like its long-eared relative, numbers of this species spend the day together, usually on the ground, on tussocks or fallen logs in tangled places, where they will allow one to approach very closely before flushing. They then rise silently and fly off a short distance to drop noiselessly back into the tall grasses.

The commonest owl of all is the little screech owl, not much larger than a robin but much heavier since but little of its length is given up to bill or tail. It is found even in the heart of large cities in hollows of trees or in crevices about buildings, for the mice upon which it feeds are everywhere. It is represented by one or another of its nine races in all parts of North America. In color it varies from grayish brown to brownish red, the different colors having no bearing upon age, sex or season. This unusual phenomenon is known as "dimorphism" and has never been satisfactorily explained. Like the great-horned and long-eared owls, it has conspicuous ear tufts, but it is easily distinguished by its small size. When seen during the twilight when it starts on the night's hunting, the ear tufts are frequently laid so far back as to be indistinguishable and the head looks round as in the saw-whet owl.

The note of the screech owl, very far from being a screech, is a low tremulous whistle, sometimes almost a wail.

The saw-whet or Acadian owl is the smallest of the owls found in eastern United States, being only 8 inches long. It is usually encountered during the day in evergreen thickets, thorn bushes or other thick places and frequently is so tame or sleeps so soundly as to allow itself to be taken in the hand.

In the plains region of the West and in southern Florida occurs the burrowing owl, a strange little round-headed bird with legs longer than most owls' because of its terrestrial habits. The western owl lives in the prairie dog towns, but the Florida owl digs its own burrow in the sandy soil.

The two smallest owls are the pygmy and elf owls of the Southwest. The former is a diurnal bird flying around even in the bright sun in its pursuit of insects. It measures $6\frac{1}{2}$ to $7\frac{1}{2}$ inches in length and is about an inch longer than the tiny elf owl. The latter spends its days in woodpecker holes, particularly those in the giant cactus, and, like other owls, comes out at night to feed.

Another diurnal owl and by far the most hawk-like of all the owls is the hawk owl. It is a gray and brown bird somewhat larger than the long-eared owl and without ear tufts. Its tail is conspicuously longer than in other owls, which adds to its hawk-like appearance. It inhabits northern North America and comes southward in winter rather erratically.

The second family of owls, *Aluconidæ*, are called the "barn owls". There are about 25 species and sub-species, found especially in the warmer parts of the world. All are similar in color and habits although they vary in size. They differ from the other owls in having long slender legs and nearly white underparts speckled with black. The back is a very light mixture of tan and gray. The facial disc is continuous all about the face, which together with the black eye gives them a curious half human expression, so much so, in fact, that local newspapers sometimes announce the capture of a strange bird, half bird and half monkey, and one of its common names is the monkey-faced owl.

There is but one species of barn owl found in North America, occurring from the Atlantic to the Pacific, occasionally as far north as New York and New England. It lives about deserted buildings, towers and cupolas and is a most efficient mouse-trap, catching from three to six or more mice every night.

The majority of owls lay their eggs in cavities in trees without any pretense at a nest, but sometimes when these are not available, they utilize old nests of crows, hawks or even squirrels. The short-eared and snowy owls regularly lay their eggs in crude nests on the ground and the barn owls in buildings. All lay pure white, almost spherical eggs. The young are thickly covered with down when hatched and early learn the art of self-defense by dropping their wings, shaking out their feathers, as shown in the illustration of the young long-eared owls on page 3477, and then either clapping their bills or hissing.

When on the nest, the majority of owls sit very closely and allow themselves to be captured in the holes but others, like the great-horned, are usually very wary and will even desert the nest if molested. Owls

usually begin to incubate as soon as the first egg is laid, sometimes both birds sitting on the nest side by side. Since the eggs are not laid regularly each day, as with most birds, the first eggs hatch much sooner than the last, and the young birds in a nest are often of very different ages.

If a mother owl is captured with her young and confined in a cage with them, she will frequently devour them, even though she be well fed. They are quite bold in the defense of their young, particularly after dark, when if one ventures too close, he will often get eight holes in his scalp from the talons of the old bird.

Owls respond very readily to an imitation of their calls and will often come from considerable distances to investigate their supposed rivals.

Many interesting chapters of natural history might be written about owls and the average person would be willing to believe almost anything that might be told in them, but when all that is known has been said, the book of owl lore will be far from complete because their real life is just beginning when darkness obscures them.



FLASHLIGHT OF A SCREECH OWL
Returning to its young with a large moth.



YOUNG WALTER RALEIGH LISTENING ENTHRALLED TO A MARINER'S STORY OF THE NEW WORLD WHICH IN LATER YEARS HE HELPED TO EXPLORE
From the painting by Sir John Everett Millais, in the National Gallery

MEMORY AND ATTENTION

How We Retain Interesting Experiences, Recollect
Them, and Recognize Them when They are Recalled

THE ART AND SECRET OF LEARNING

HAVING studied the facts of sensation, and the way in which we associate the impressions which we have derived from sensation, we have already had plenty of occasion to observe the vital property called memory. Only a few points need reference before we pass on to more difficult matters.

First, we have seen that, in the philosophical sense, all living things remember, and they alone remember. We are thus the sum and issue of all our past. Probably nothing is forgotten — somewhere. Once and for all, we sharply distinguish between the primary fact of memory, which is *retention*, and the secondary fact, depending on the first, which we call *recollection*. We all know quite well that, when we say we “can’t remember”, we mean that we cannot recall what, in fact, we know to be remembered somewhere within us. We say, “It will come back to me in a minute, though it has slipped my memory just now.” Obviously, common speech here, as usually, confounds two distinct things, and on consideration we see that the process of retention and the process of recollection are quite distinct. Each of these two processes requires some comment, but first we must observe that there is a third process involved in memory, which we call recognition. We may retain, and recall, and then not recognize the memory in question. We may fail to recognize what, in fact, we remember, such as the face of someone who greets us with the infuriating observation, “I’m sure you don’t remember me.” There the word “remember” covers more meanings than one.

You do remember the face, in the sense that it has been retained in memory, for you know that you have seen the man somewhere before. But for the life of you you cannot remember where. In a word, the act of memory which we call recognition has failed. But if he follows up his ingratiating introduction by a series of hints — “Last summer”, “The best of afternoon parties”, “A tennis match” — at any moment the act of recognition may follow. Now let us note these three constituents of memory in their natural order.

Retention, the primary fact, is natural to all life, as we have seen, but its intensity varies. The degree of retentiveness is probably a native characteristic of the individual, and is to be treated as such. Disease or intoxication or senility or shock may diminish or destroy it. It varies in the course of the individual life. During some years before puberty, sheer retention is often extraordinarily accurate and easy. The child remembers names, poetry and so forth with incredible ease. Shortly this acuity diminishes markedly, and few adults can remember as they did in their teens, if by remembering we mean merely retention. In senility the decadence of the power to retain is very marked. The memory of the remote past remains, because the retentions were made by younger nervous tissue, but new retentions are made with difficulty, so that recent facts are not remembered, though remote ones, which we might think more difficult to remember, are accurately retained and reproduced. The explanation of this paradox is now apparent.

The most important fact about mere retention-memory, after its universal character, and its indispensableness for all the higher operations and possibilities of the mind, doubtless is that, so far as we can discover, it is what it is, and will be what it will be, except that it can be damaged. It cannot be improved or educated. Education of the right kind will do marvelous things for the memory, but not for this part of the memory. It follows that all "learning by heart" — "To know by heart is not to know," say the wise French — and all schemes and education which assume the value of such rote-learning, must be condemned. Certainly it is necessary to retain, and if these methods increased the power of retention they would be valuable, however worthless the subject-matter, however tiresome the process. The psychological condemnation of these methods depends upon the fact that they do nothing for the retention-memory, while they neglect and often injure the higher parts of the memory, which can be educated.

Value in the subject-matter the only excuse for learning by rote

For all learning by rote, then, two warnings henceforth can alone be admitted. One is that this is a discipline. On that we need say no more than to deplore the existence of those who have no higher and deeper ideas of discipline than the enforcement of what is wearisome, for no worthy end. The second is that the subject-matter of what is taught may have value in itself. Thus, it neither improves the memory nor the reason to learn that "through" and "though" and "trough" are pronounced as they are, but it is useful. What one requires thus to remember, as distinguished from what should properly stay in reference books, until the man who has a really educated memory finds his sure way to it, may therefore be taught by rote and repetition; and even what was not appreciated at the time, like poetry, may be gratefully remembered afterwards. But this purely mechanical method of schooling is not to be called education, and must be sharply limited in its employment.

Impossibility of finding anything in the brain that corresponds to memories

It need hardly be said that to teach by rote requires no qualities on the part of the teacher, and is therefore the natural resort of the idle and incompetent, who may thus readily be identified, where the teacher has any choice at all. Of course, no reference is here made to those who teach as they must, thanks to the demands of red-tape and examinations.

What fact, in terms of nerve-cell and fiber, corresponds to retention, no man can say. No doubt there is some physical fact which corresponds to the psychical fact, but when the physiologist and the microscopist are challenged as to the physical basis of memory they have no answer. The brain of any one of us is somehow the storehouse of a vast variety of memories, of words, experiences, people, things, which were not there once. No one could make sections of such a brain and point to the appearances, under the microscope, which correspond to these memories, and which would not have been there ten or twenty years before.

No observation has distinguished between the speech center of a linguist and that of a peasant whose vocabulary only contains three hundred words, or between the music center of a great conductor who can conduct fifty operas and symphonies without the score, and that of a man who only knows bits of a few tunes, and knows those wrong. Yet, whatever our theory of mind and body, whether we follow Haeckel or Bergson, Lucretius or Plato, we are all agreed that there must be some material difference in the brain which stores memories, as compared with that same brain before they were stored.

The marvelous book of the brain kept in invisible type

The sheer amount of what the brain can retain is staggering. A great linguist or philologist, a great man of science, expert in some department, but with a vision of the whole, a monarch like Napoleon — such people have brains the memory contents of which could not be written out

in years, and which could not be printed, in any visible type, except in a number of volumes which would many times outweigh the whole brain in question, and many times more the gray matter, which alone remembers. If things be "printed" on the brain, the type is ultramicroscopic. We have said we know nothing as to the material basis of memory, but at least we know that the nerve-fibers do not remember, can have no more memory than telephone wires of the conversations they transmit. We are therefore reasonably certain that it is the nerve-cells which remember, and we can say no more.

The total weight of the gray matter of the brain, apart from the blood in it, is a matter of a relatively few grains. True, there are many millions of cells, and when our minds are utterly baffled by the fact of memory, they must try to get what reasonable satisfaction they can out of this huge number. Many cells may be involved, must be involved, in what, for us, is one memory; and each memory of the millions which our brains soon come to contain may correspond to a special combination of an unknown number of cells. But all this is speculation; the fact is that we know nothing, and the more we learn the more we feel forced back to the old view, long scoffed at, of the psychical entity, the soul, which indeed is the seat of memory, and which, in some inconceivable fashion, employs various portions and combinations of the organ we call the brain.

The physical condition of the brain vital for memory

If, on the other hand, we feel inclined to rest in this conclusion, and to let the study of the brain "slide", we must learn how vital for memory is the physical condition of the brain. A mere rough shaking of the brain, producing what is called concussion, may completely obliterate memory; the condition produced by asphyxia, as in drowning, may revive memories thought to be long lost; various intoxications will ruin memory; and in all these cases we can only say that some physical change has taken place, but of its nature no one knows anything.

The second function of memory, which we have called recollection, and the third function, which is the recognition of what is recollected, can be defined in terms of association, as we are already aware, and as is indicated in the process by which a half-remembered stranger restores himself to our recollection. He rouses one association after another until recognition is thereby attained. But the supremely important fact about these two functions of memory is their entire oppositeness to the primary retention in respect of educability. These can be educated, by association, by making many and relevant associations; and therefore, while education is impossible and only disastrous in respect of what rote-learning is designed for, real education is invaluable for its services to these higher functions of memory.

The wonders of associative memory in clever men

There is no mistaking the brain, originally of high quality, in which the associative memory has been properly trained. Its freedom depends upon its chains. In speech or in writing, the possessor of such a memory shows himself at once. It is not necessarily that he remembers names, dates, numbers, like some of the extraordinary persons occasionally seen in theaters, in whom the retention-memory is developed beyond all belief, but who may be nearly imbecile in all essentials. The people of whom we speak may have retention-memories of any class. Their strength is in the chains of association. The mind travels, "quick as thought", "from grave to gay, from lively to severe". The apt illustration, the right quotation — which may or may not be verbally accurate but retains its point, by which it was then and there remembered — the just marshaling of relevant facts, all these are essentially feats of memory.

In times past, retention-memory had its uses, because tradition was the only means of preserving knowledge and achievement. The old man who could retain what he had been taught, and pass it on to his juniors, was necessary for the maintenance and advance of primitive civilization.

Today the arts of writing and printing serve the purposes of retention-memory to perfection, and to regard education as the development of this kind of memory, even if that were possible, is to place man lower than his own inventions.

The right and the wrong methods of utilizing the memory

The object of education is no longer to make a man into a "walking encyclopædia", but (among other things) to make him capable of using an encyclopædia. The great workers and students and thinkers deliberately refrain from the attempt to memorize things. They value their brains and their time far too highly. What lesser people strive to retain for use, these merely know where to find; and the knowledge does not fail them at the right moment, in speech or thought, though the others, who have it all in their heads, may never be able to use it.

This contrast, upon which we cannot too earnestly insist, is never better seen than in the methods of different students, following lecture or book. One will boast that he has gotten down every word, and will then try to memorize the whole. If he is questioned suitably, he can reproduce it all, at examination, like the guide at a show place. If he be asked another question, which requires the associative use of this piece of knowledge, it simply fails him. He has the wrong kind of memory. His is the memory of a talking-machine; he is making himself into a parrot instead of a man, which appears to be the aim of most of our present education. The other student merely listened to the lecture, perhaps with a jotting or two; he may have "read" the book in three hours, where his fellow spent three weeks. But he has gotten hold of the chains, he knows the ropes, and he will pull them when required. That book and its contents are his henceforth, though he owns no copy, and may not refer to it again for a decade. When the need arises, his mind will tell him that he must look up a certain chapter, or will even save him so much trouble as that. And, of course, the man's processes seem magical to the "Victrola", poor fellow.

Misdirected labor of trying to improve retention instead of association

"He who has learned how to learn can learn anything," said Carlyle, who was a great learner, and knew. We see at once what he means. And the reason why this analysis of memory is so necessary, and is being reinforced here with every kind of illustration, is that, in ignorance of psychology, the world of education is full of misdirected labor. National education and self-education, the work in our medical schools and everywhere else, is vitiated right and left by the lack of a clear understanding of the facts of that which we are trying to educate. After leaving school, most of us realize that the time has come for our education to begin, and we look about us for methods and for advice. People are to be found who undertake to improve our memory for the purposes of learning, and we go to their lectures or read their books. But we must distinguish between them, for ourselves, on the basis of the psychological analysis which is here made.

If they try to improve retention, let us have no more to do with them. It cannot be done, nor is it worth doing, except for the purposes of examination by imbeciles in high places. If they try to stamp things into the mind by any process of repetition, however disguised, then we may know that they have not the root of the matter in them.

The indelible engravings made by associative memory without repetitions

The one mechanical fact, so to say, that we know about the elementary, universal fact of retention-memory in living things is that it largely depends on repetition. You hear your own name and write it so often that you are not likely to forget it — "I know it as well as my own name." So with languages or anything else. But associative memory is essentially independent of repetition. In very many instances the association, once made, and never repeated, is there permanently. Most of us have such associations which we would gladly be rid of, but we never will.

The event was never repeated, but the association is engraved indelibly in the memory, and that name, that tune, that odor, that place, will recall something else to the end of our days. Everyone who has had a great teacher can recall the place where he stood and heard his master say some memorable thing, and the name and the place and the saying are associated forever, though never before or since were those words said. Contrast this case with the task of getting up a list of dates, and the only method which will there avail.

Alike for retention, recollection and recognition, there is a factor to which we have not yet referred, but which is of overwhelming importance. We may call it interest, or we may call it attention, and it is both. If we are interested, we attend; and if we attend, and largely in proportion as we attend, we remember. If our interest be intense, our attention is intense, and the memory will be more durable. The literal meaning of the word "interest" is the key to this fundamental fact of psychology. The Latin verb "interesse" means to "be among".

Vital interest the master-secret of true memory

Interest is a vital state of relation to something which *vitally* concerns us, so that *we* are among and within it. Everyone is interested when an automobile threatens to run over him, when his house is on fire or rocks with an earthquake; and we are apt to remember these occasions. The deepest nature of a human being is thus exposed in his interests and memories. The selfish man is interested in and remembers only what concerns him — "A pimple on his nose interests him more than a cancer in his neighbor's mouth", as the writer once heard one of his teachers say. Most of us are more interested in, and will better remember, a scandal next door (which was not true, anyway) than an epidemic or tidal wave or famine that has destroyed millions in China, though we read about it, with languid interest, every day for weeks. Not magnitude, not repetition, but interest dominates; and what shall interest, what we shall feel that we

"are among", depends on what we ourselves are. It depends on our deepest nature and our experience. You have never been to Copenhagen, and news therefrom scarcely moves you; or you once spent a long holiday there, and everything you can see about it interests you. This is clearly a case of interest aroused by association and ultimately depending on interest in the literal sense again; it is *your* Copenhagen, *you* were once there. We all know selfish or small-minded people who, in conversation, respond or revert to only those things which interest them, because they have been to the place, they know the author, their aristocratic friend has seen the play and so forth.

Everyone can distinguish, in conversation, the man who is interested in himself, and the man who is interested in *us*. What associations does his tongue run to!

The will to live roused spontaneously by that which fascinates us

Nothing could be more obvious, more important, more elementary, than this principle. Yet, clear, cogent, universal though the principle be, the greater part of all education flouts it, ignores it, seems deliberately calculated to insult it. We want the boy, the girl, the student, ourselves, to remember; then we must arouse interest. Somehow, their "will to live", their *élan vital*, as Bergson calls it, the thrust of their lives, must be engaged along this line. We may succeed, honestly or dishonestly. The child may care nothing for the subject, but much for the prize. We get his interest, and he learns: more shame to all concerned. No child in Japan can work for prizes, for there are no prizes.

Or we are interested because the subject simply fascinates us, and so we learn; or the personality of the teacher or his way of writing is irresistible, and we read what we would never have expected to find ourselves reading. Some strength, kindliness, knowledge, humor, passion, in the author interests us, because these vital qualities serve our lives, thus interesting the deepest thing in us, which is the will to live; and we listen.

Concentration by shutting out the things that do not interest us

We may have heard the same thing a hundred times before, but we have forgotten it; now we remember.

We forgot because our interest was not aroused, our attention was not secured; the deepest *we* of us was not really there at the time. Compare half a dozen people reading the same paper, and all this is illustrated. They all glance down all the columns. One could never tell you that there was anything in them about baseball, or tuberculosis, or the weather; another saw nothing else. The eye at once forgets what it did not want to see.

But we must leave this primary fact, with all it means for teaching and learning, and examine the exact mechanism by which interest works out in attention, and thence in memory. Here we are all indebted to Professor Charles Sherrington, of Oxford, who devoted many years to the physiology of attention in terms of reflex action. His study shows how, despite the incredible complexity of the nervous system, we are able to attend, to be single and devoted, to one thing at a time, to the exclusion of others. It is then, when we are in "rapt attention", based upon vital interest, bodily or mental, that we remember.

Even in a very simple nervous system, and far more in ours, any sensory nerve may carry impulses that run out, so to speak, along any of many motor nerves. Thus, unless some guiding principle be at work, all impulses, coming through eye, ear, skin and so forth, will issue in acts of attention or of motion, all helter-skelter and perhaps contradictory.

Inhibitory action of nervous system giving precedence to main interest

But Professor Sherrington has found, in all the types of nervous system that he has examined, and not least in man's, the existence of what he calls a *common path*, along which sensory impulses must travel before they produce results. And the point is that this common path is like the "party" line of a telephone. One subscriber is talking to someone over the phone.

Meanwhile another subscriber on the same "party line" wants to use the phone. "Central" softly tells the second person that the "line is busy". The second subscriber to the line must wait until the first subscriber finishes his conversation. The first subscriber occupies the common path, and blocks the line for the other. This is exactly what Professor Sherrington has proved to be true of reflexes in general. They inhibit one another, fortunately for us. If one sensory or ingoing impulse gains possession of the common path, the others must wait. He gives a beautiful illustration showing this vital unity of the nervous system in practical working, and the fashion in which what dominates by its interest monopolizes attention, and so makes its impression upon memory.

The brain's impulse to deal with one thing at a time

Suppose two objects simultaneously presented to the eye, but seen not by the center of the retina, but "out of the corner of the eye", as we say. Either of these two objects alone would excite exactly such a reflex action as would swing the eye round so that the light from the object in question would impinge upon the "yellow spot", the most sensitive part of the retina. What, then, happens when two objects simultaneously attempt to gain the individual attention of the eye? If they lie to the right of the field of vision, and in a horizontal line, will the two stimuli be *summed*, as physiologists say, so that the eye swings round nearly twice as far as it should, and thus obtains a good view of neither object? Or will the eye respond to the difference between the two stimuli, with the result that it swings round too far for the clearest vision of the one object and not far enough for the clearest vision of the other? Neither of these undesirable events happens. One impulse or the other gains complete control of the common path, to the entire exclusion of its rival, and the eye is fixed upon whichever object has the most interest in it, and the other is as if it were not there. Try to teach a class of children the exports of Brazil when a fire-engine is dashing past the window!

The theory that attention is an act of the will

We cannot explain attention except with such help as Professor Sherrington affords us, and with some reference to the will. The fact that attention is related to will, subconscious or conscious, is evident to anyone who remembers an occasion when his attention began to wander and was forcibly recalled, as when you are talking to, or being talked to by, a dull person, and find yourself listening to someone else, who is interesting. Professor Wundt, the great German psychologist, has argued that attention is essentially an act of will; and if our view of will is deep enough, and includes the "will to live", which animates the whole of our behavior, we may agree with him. At any rate, the telephone analogy holds good; and the idea of the "party line" illuminates the problem of attention, and the fact of our amazing unity of interest, attention, response and memory, notwithstanding the variety of things that pour in upon us, and the measureless multiplicity of our nervous possibilities of attention and response. When we attend to a voice or a sight, to the exclusion of other things, what is it but the complete possession of the "common path" by the sensory impulses excited by the object in question? In consequence of their control of the common path, these impulses are able to command all the muscles which subserve attention. For it must be remembered that there is a very definite motor or muscular factor in attention; and so much the more do we see it to be a positive act of will, and not something of which we are the passive object.

The absorption possible when a dominating influence commands the nerve tracts

For instance, you are enraptured by a great singer at the end of an opera. In vain part of you says to part of yourself, "You'll be late for your train," nor are you aware of the fact that the man next you is standing on your feet as well as his own. The singer has exclusive use of the common path. And what is the motor aspect of this state of strained attention,

as we significantly call it? You cannot cock your ears forward, though the muscles are there and you would use them if you could. But the *tenses tympani* are tightening the drums of your ears, so that they may respond to aerial vibrations with as little loss as possible. Many muscles of the trunk are in contraction, so that your body may be rigid and make no sound. "The audience was held breathless," we say: so eager are you that you even hold your breath. The singer has gained such exclusive possession of the common path that even the reflex action of breathing is interfered with, for a time. Your eyes are fixed, your pupils dilated, and, in extreme cases, muscular tissue behind the eyeballs is excited and pushes them forwards, lest they miss anything. Perhaps the sensory nerves of the spine are also excited, so that you feel "cold shivers down your back", while the secretory nerves of your tear glands may be violently stimulated.

Interest, attention, and memory the highway of learning

Thus complex is the combination of reflex actions which constitute the act of attention in this instance, though the exciting impulse is only single (if you cannot see the stage), or at most double, if you can see and hear. The dominant interest, proceeding from the stage, has gained the common path; all other things cease to exist for the time, are neither noticed then, nor likely to be remembered afterwards. This interest, acting through the common path, ramifies in many different directions, affecting motion, secretion, sensation, through as many different nerves, but all harmoniously and to the one end, expressive of the one interest. These are the occasions we are likely to remember.

Interest, attention, memory is the sequence, and here the teacher and the student must follow the indications of psychology. In such a case as we have quoted, the beauty of the sound, the personality of the singer, the "human interest" of the story, suffice to gain the attention, and the rest follows. But in a thousand everyday cases interest cannot be aroused at first, and the teacher despairs

of getting results. How is he to succeed? The first recourse may be had to the old method of repetition. Even without interest, sheer repetition, acting in some mechanical way, may do something. If the class will not be interested, and learn in that way, it must go over the thing time and again, and learn in that way. But the wiser teacher makes a better choice between the two alternatives which are offered him. The one is repetition, failing interest. The other is to arouse interest, and then all will be well, with little need of repetition, no drudgery, and permanent results.

Heartbreaking dullness enlivened by the magic of association

But how arouse interest, where none exists, in a subject which must be dealt with? Only through association can this be done. You must proceed from the already known and interesting to the unknown and uninteresting. Where nothing already exists in the pupil's mind, from which a start may be made, the case is hopeless. Where there are no rational associations, as in the spelling of many words, many dates, irregular verbs, or none which can be discerned except by the expert philologist, or the historian who knows what other events happened and what people were alive in any given decade, there also the case is hopeless. No one should be set to teach such things so. But elsewhere the associations can always be found. That is why the most modern education, here and there, is so promising and delightful.

Where, for instance, science is taught to boys, beginning as Faraday began with his "Chemical History of a Candle", or as anyone may begin with the obvious facts of a boy's own body, interest is aroused and the rest follows, because we proceed from what is already interesting and make chains from it outwards. No man living,

no devoted student, no "dry-as-dust" professor, would or could begin in the middle of any science. We must proceed by association from the near and vital, and then all will be vitalized. The dry-as-dust professor is just doing what the reader of the "Sporting Final" is doing — studying what interests him; only he has a long series of associations which we do not see. These are what sustain every student. He may be engaged in the differential chemistry of certain sub-molecules in the group of compounds called "albumins", but he could never begin there, for it would be too heartbreaking and meaningless. He got there by a chain which began with a natural interest in eggs and milk and life and death; and he hopes that, some day, he will find the key to cancer along this line.

A man's worth shown by what he is interested in

Let no mistake be made, the man of science pursues his interests like everyone else. And the moral is that we should treat every student on the same lines. If Newton and Darwin could not study gravitation or variation except by means of an approach, through association, which made these things vital to them, children and all students must be treated as well. Somehow we must make the vital bridge, from daily experience or concern, outwards and onwards, until the child, or the philosopher, finds himself studying and remembering and searching among things which, in themselves, seem destitute of meaning or interest or worth. Thus the secret of self-development is the making of associations from vital things towards vital things, and the extension of our lives, and their creative power, into everything we touch with our minds. And thus we all reveal ourselves. The worth of any man, said Marcus Aurelius, is the worth of the things he is interested in.



TUNNELING THE EARTH

How by Tunneling Man has made New Avenues for
Traffic and Pierced Nature's most Stupendous Obstacles

MOUNTAIN, SEA AND CITY UNDERMINED

THE Egyptians, Chaldeans, Hindus, Aztecs, Greeks and Romans were all famous for their work under ground, and the feats which they accomplished seem almost incredible when it is remembered that they had only the simplest of tools and were unaided by the rock drills, air compressors, dynamite, tunnel shields and a hundred other inventions at the modern engineer's command. Today works which surpass the wildest dreams of the ancients are accomplished as ordinary feats, all "in the day's work", receiving no more than passing mention.

Rushing trains bear their passengers under high mountains and beneath harbors and rivers; water supplies are brought to cities through tunnels miles in length, and the earth beneath our metropolitan centers is a veritable honeycomb of underground passages which carry traffic or serve as conduits for water, heat, gas, electricity and mails.

One of the oldest large tunnels in the world was built by the Romans under Monte Salviano for the drawing of surplus water from Lake Fucino, which had no natural outlet. It was $3\frac{1}{2}$ miles in length, and was in places 400 feet below the surface. It was designed to have a width of 6 feet and a height of 10 feet, but when in 1862 it was opened after having been closed for centuries, it was found to be very irregular in its section. It is stated by Pliny that 30,000 men were employed for eleven years in its construction, most of the rock being removed in pails having a capacity of less than 2 cubic feet.

The longest railroad tunnel in the world is the Simplon, under the Alps, having a length of $12\frac{1}{2}$ miles. Next to this in

length comes one at Schemnitz, Hungary, constructed to carry off the water from the mines. This is 10.27 miles long and holds the record for slow construction, having occupied 96 years in its building, from 1782 to 1878. Its section measured 9 feet 10 inches high and 5 feet 3 inches wide. Its total cost was about \$5,000,000 or \$92 per foot of length.

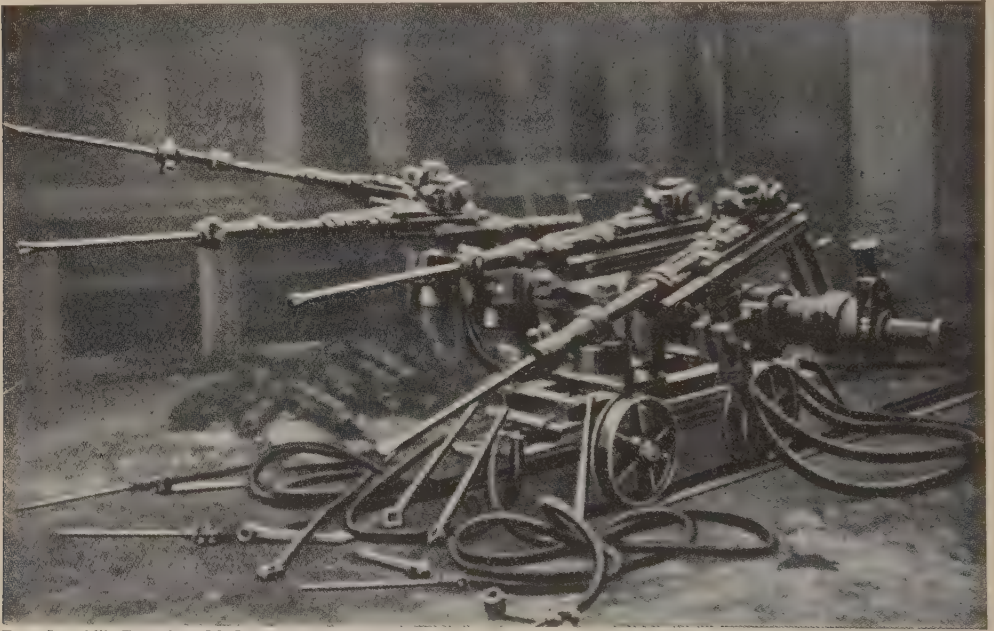
Tunnels like the Lake Fucino and the Schemnitz are very tedious in constructing and often dangerous, but they are simple compared with tunneling under high mountains or under harbors and rivers. In the former case, vertical shafts are generally sunk at intervals along the proposed line, and these provide not only means for removing excavated material ("muck"), but also for aligning the tunnel and ventilating it during construction and afterward. Ventilation in deep and long tunnels becomes a most important factor. Shafts cannot well be sunk in the case of high mountains or under-water work. Other methods must be followed which are accompanied by more or less hazard.

The great era of tunnel building began with the development of the steam railroad, and the ever increasing demands of transportation have been the incentive of the tunnel engineer. The construction of the early tunnels must have entailed difficulties and hardships beyond the present-day experiences. The men toiled with pick and hand-drill in dim candle-light surrounded by darkness and unprotected against cave-ins, hidden streams of water, heat and near-suffocation. No mechanical appliances were available for help, and ill-health and death were only too often the ultimate reward of the laborer.

For instance, in the construction of the great St. Gothard Tunnel under the Alps, the loss was appalling, totaling 800. Today, tunneling is, comparatively speaking, a fairly safe occupation. This has been brought about by the invention of the tunneling shield and the use of air compressors to furnish fresh air to the workers and power to operate the large rock drills. The most imposing triumphs of man in rock tunneling have been won in the piercing of the Alps by four different tunnels, the Mont Cenis, the Arlberg, the St. Gothard and the Simplon. These

Generally, borings through solid rock are left without further finish, no linings being required unless a smooth surface is desired, as in tunnels for conveying water.

The Mont Cenis Tunnel was completed in 1871 and is 7.5 miles long, passing under the highest point of the mountain at a depth of 5275 feet. The St. Gothard, opened in 1881, is 9.25 miles long. The Arlberg, 1883, is 6.5 miles in length, and the Simplon, opened in 1905, is 12.25 miles long. As stated elsewhere this is the longest railroad tunnel in the world, and its cost is placed at about \$11,750,000.



From Lauchli's *Tunneling*, McGraw-Hill Book Co.

DRILL CARRIAGE USED IN A SWISS TUNNEL

are the names of the great passes under which the tunnels were driven. The borings in all four cases were made by use of rock drills and high-power explosives. The Mont Cenis, the first of the four, was also the first tunnel in which this method was employed. The drill was driven by compressed air carried from the power plant through lines of piping.

When solid rock is drilled, the whole face is seldom blasted out at once, but a narrow opening or "drift", as it is called, is opened up at the side or bottom of the "heading", and the loosening of the remainder is a comparatively easy task.

Its cost per foot, however (approximately \$180), was only about one-half that of the Mont Cenis Tunnel, built thirty-four years earlier. Its average progress per day was also greater, being close to 27 feet, while that of the Mont Cenis was only 7.5 feet, and this notwithstanding the fact that the interruptions to the progress of the work were more serious than those which occurred in the Mont Cenis. All of which goes to show the rapid advance which was made in methods and machinery. The boring of the St. Gothard occupied nine and a quarter years of continuous labor, day and night, making the

progress about one mile per year. It gave nearly continuous employment to about 3500 men. Water power was developed at each end of the tunnel to drive air compressors. Fifteen hundred horse-power was thus obtained at the Göschenen end and eleven hundred at the Airolo end. Locomotives driven by compressed air were used in hauling away the excavated material. This tunnel cost about \$235 per foot of length.

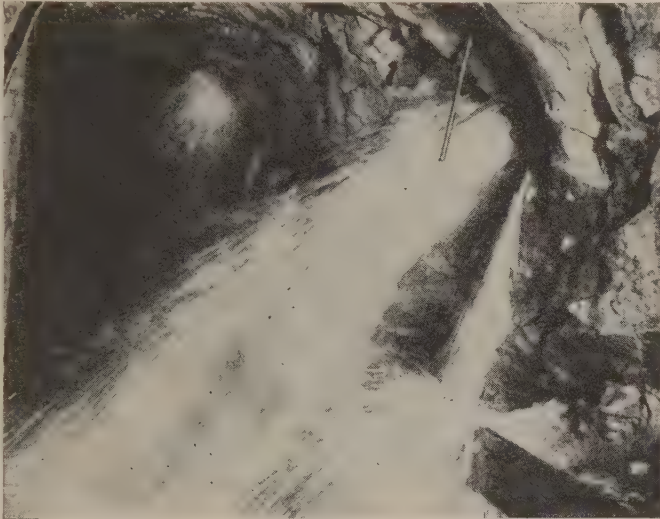
The Simplon Tunnel occupied seven years in construction. It comprises two separate tunnels, running parallel to each other, the second being a smaller one for ventilation. The main tunnel is 14 feet 9 inches wide at the rail level and 18 feet high at its center.

Exceptional difficulties were encountered in constructing these Alpine tunnels. The temperature increased as the tunnels penetrated deeper, and as the height of the mountains increased. In the St. Gothard, just before the headings met, it was as high as 93° F. This caused serious delays in the progress of the work. Men were not able to do so much. The ventilation also proved insufficient, and many men and horses were suffocated by the gases generated from the dynamite in blasting. It was estimated that the actual work done was lessened by one-half, a serious loss on the labor of three thousand men. Yet 4,476,000 cubic feet of air were being pumped into the heading daily. The ventilation in the St. Gothard, after the completion of the tunnel, is performed by nature alone. A current of air is set up by the difference in barometric pressure which exists at the two sides of the Alps.

A very remarkable and unusual experience in the St. Gothard was the sinking of about a hundred yards in length of a completed portion of the tunnel. This was due to the strata there being composed of calcareous materials which swell and disintegrate with absorption of water. Ultimately the section was enlarged and thickly lined with granite masonry.

Another famous tunnel is that which was driven to carry the old Troy and Greenfield Railway (now a part of the Boston and Maine) under the Hoosac Mountains in western Massachusetts. It stands as the result of sixteen years of labor, having been begun in 1858 and

finished in 1874. Its length is $4\frac{3}{4}$ miles and the cost of construction about \$10,000,000. Although its construction if undertaken at the present time would entail no very great or difficult problems, it must be acknowledged that it was at that time a great engineering feat. It was

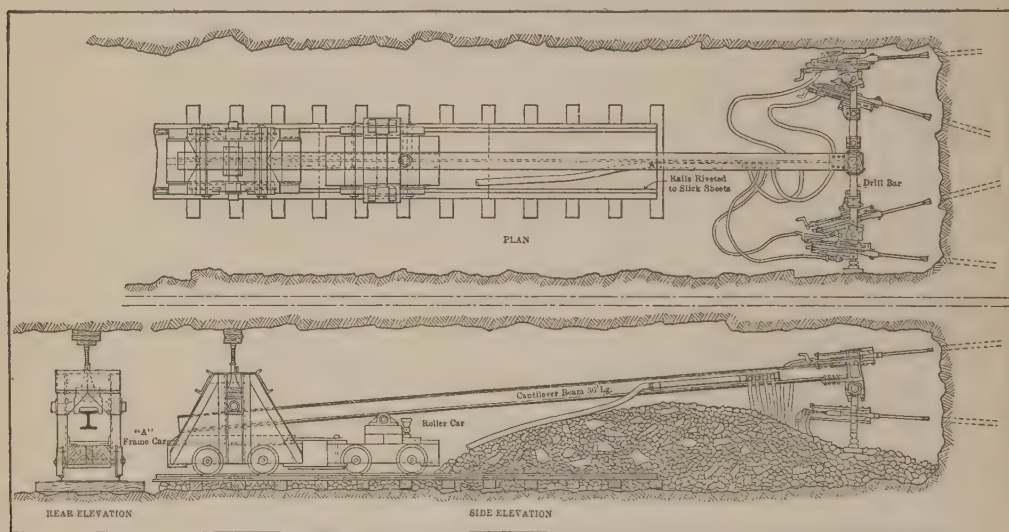


UNDERGROUND STREAMS OF WATER ENCOUNTERED IN THE SIMPLON TUNNEL

driven through a mica schist of almost granite hardness, at first by the use of the hand drill and black powder, but later by the aid of machine rock drills and dynamite, both of which came into use about this time. The tunnel was contemporaneous in construction with the Mont Cenis, and many of the men employed were in fact brought to this country upon the completion of the latter tunnel. The delays and interruptions were many and numerous, but mostly due to failure of the early drilling machines and several changes in engineers and contractors. The work of removing the material and the alignment of the tunnel was facilitated by the sinking of vertical shafts from the

mountain top to the tunnel grade. These, also, furnished means for ventilation during construction. It was in connection with one of these tunnels that the worst accident during the work occurred. The central shaft had been sunk to a depth of 583 feet, or about half its final depth, when a fire broke out in the large house which had been built over the shaft's mouth, and used as a general storehouse and office. There were thirteen miners at work at the bottom of the shaft at the time, and an effort was made to rescue them by means of the hoisting bucket, but without success. The fire burned away the cable, dropping the heavy bucket, and this

The greatest difficulty and danger in boring long tunnels is due to the uncertainty as to the character of the strata which will be encountered. Though, in general, geologists are able to determine the nature of the strata through which tunnels will have to pass, their information is not always reliable; and however many borings are made, they do not always reveal the presence of the faults which are subsequently discovered. The most dreaded of these consists of loose, sandy materials and water. Nearly all the disasters which have occurred in tunnel making have arisen from one or both of these sources. Borings could not have



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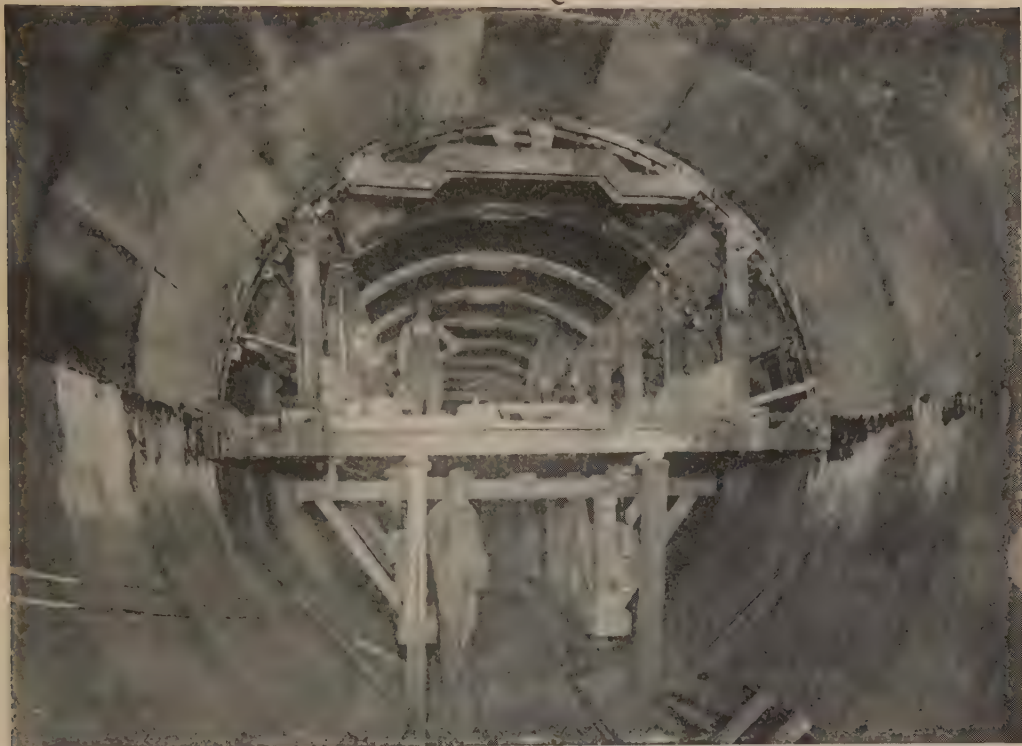
DRILL CARRIAGE USED IN MOUNT ROYAL TUNNEL

was followed shortly by the landing floor at the top of the shaft, upon which were piled three hundred hammers, drills and other steel tools. This awful shower of steel fell on the miners below, followed in a few moments by the roof timbers of the burning building. Months later when the shaft was finally cleared, the bodies of the thirteen miners were found.

Every large tunnel has its death toll, and in the Hoosac this numbered one hundred and ninety-five. Modern methods and safety devices have greatly reduced the loss of lives until now tunneling may be said to be a comparatively safe occupation.

been taken in the Alps, but geologists stated very approximately the character of the strata which would be met. On the northern side of the St. Gothard Tunnel, 6000 feet of solid granite was excavated in the dry. But on the southern side, the discharge of water from the yielding and disintegrated rock was 4000 gallons per minute, the equivalent of thirty good fire-streams. Often the drilling-machine frames had to be laid in a torrential stream, twenty inches deep. The men worked incessantly in a tropical rain descending from the roof, while frequently solid jets as thick as a man's arm burst out from floor or wall.

IN THE CATSKILL AQUEDUCT TUNNEL



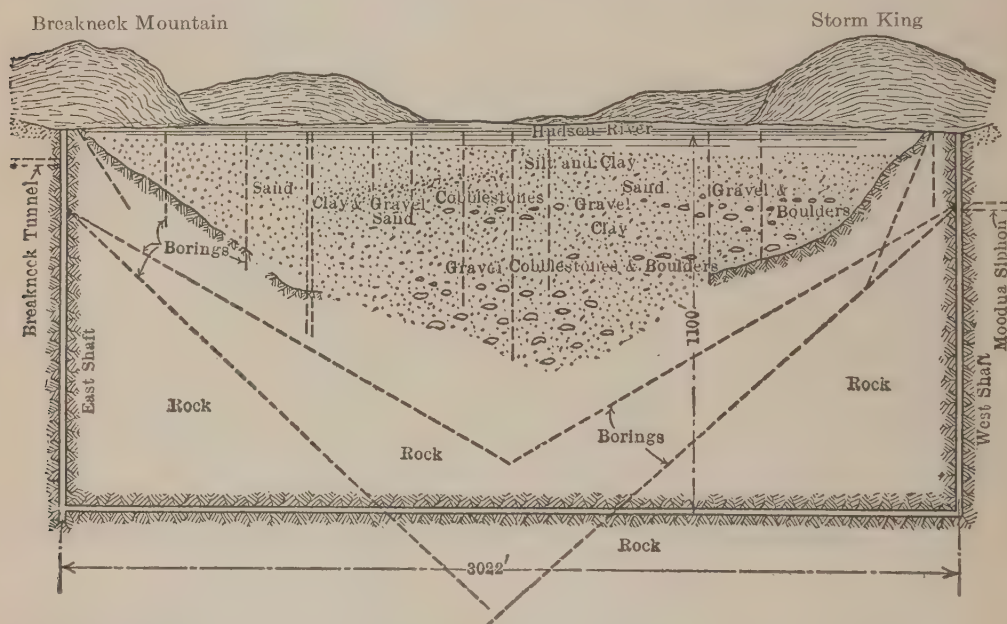
COLLAPSIBLE STEEL FORMS USED IN LINING ROOF



COMPLETED LOWER HALF OF CONCRETE LINING

To add to the difficulties, the workings were always at a high temperature which was increased by the blastings of dynamite so that 85° F. and over was recorded. The heat on the south was higher than on the north, due probably to the greater height of the mountains there. Almost worse than this is the inrush of water from hot springs, such as happened in the Simplon Tunnel. These would knock down the workmen and raise the air temperature so high that work became impossible. Cold water was then brought to mix with the hot water and lower the temperature so work could be resumed.

bridging, placing steel pipes on the river bed and tunneling, it was finally decided to adopt the latter method, locating the tunnel in the bed-rock which, in places, completely underlay the river. The project is interesting chiefly by reason of the extreme depth to which it was necessary to go and also because of the exploratory borings made before construction. The accompanying drawing shows these two features. It was necessary that solid rock be encountered throughout, not only to facilitate boring, but to prevent possible future injury to the tunnel by slipping or crushing. Borings were made at many



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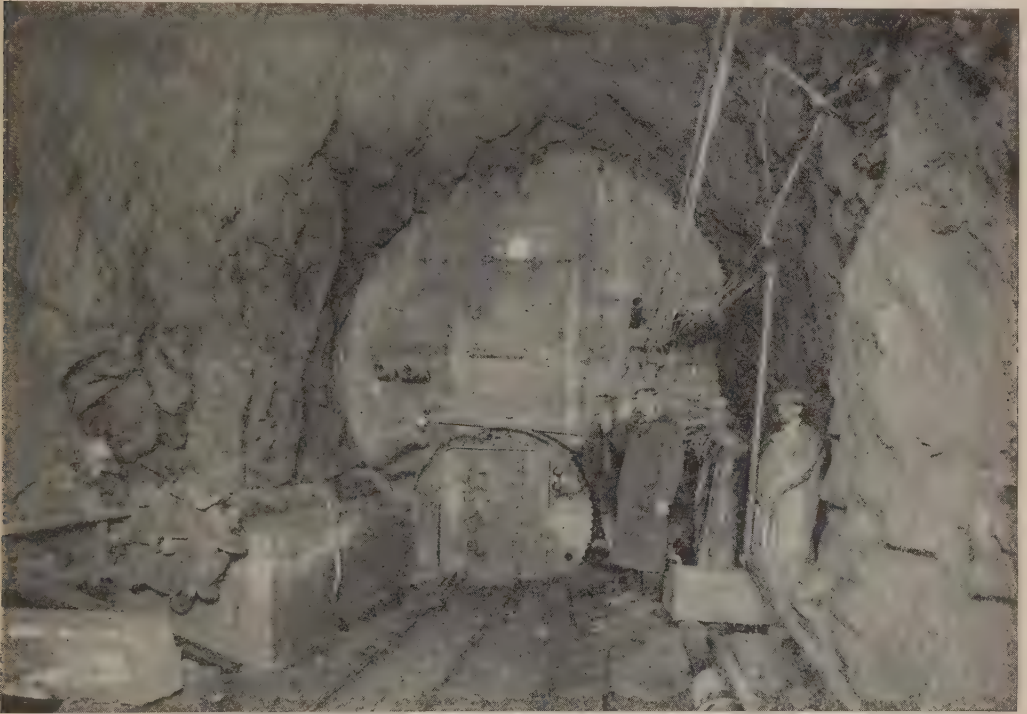
CATSKILL AQUEDUCT TUNNEL AT HUDSON RIVER CROSSING

In addition to the several hundred railroad tunnels in this country, there are a great many which have been built either for drainage purposes or to carry water supplies, and no article on tunnels would be complete without mention of the one finished in 1913 under the Hudson River at Storm King to carry the waters of the Catskill Aqueduct, described in the chapter "A City's Water Supply". To reach New York, the aqueduct had to be carried across the Hudson River, and, after comparative studies as to the advantages and disadvantages offered by

places along the proposed route, both on shore and in the channel to ascertain how far down it would be necessary to go to find such rock. The deepest of these borings were made with diamond-faced drills, and in the center of the river, where the water was about 130 feet deep, such a drill was sent to a depth of nearly 800 feet without showing positive evidences of solid rock. Inclined borings were then made from the two banks, and two sloping holes 1830 feet and 2050 feet long were driven from the east and west banks, respectively, at an angle of about 45° with

a horizontal, and they very nearly encountered each other, as may be seen in the diagram, at a depth of about 1650 feet below the surface. Two more holes about 1650 feet long were then driven at an angle of about 25° with a horizontal, intersecting each other at about 960 feet below the surface. From an examination of the borings, it was seen that the material was chiefly hard granite free from any serious seams or weak spots. One of the holes gave considerable trouble by discharging relatively large quantities of

to prevent seepage from the river. At one point, the workmen were driven back by the inrush of water from a water-bearing stratum, and no progress could be made until an 18-foot wall of concrete had been placed across the tunnel heading and by means of pipes placed through it, liquid cement (grout) forced into the leaking seams under a pressure of from 400 to 900 pounds per square inch. When this grout had hardened, the removal of the concrete bulkhead showed that the inrush of water had been reduced to a slight



CONCRETE BULKHEAD WITH LOCK, CATSKILL AQUEDUCT TUNNEL

water, showing that at some point it was finding its way from the river down through the otherwise solid rock.

It was finally decided to locate the tunnel about 1100 feet below the river surface, and this was accomplished by first sinking, on either bank, vertical shafts to this depth and then opening up horizontal headings. The length of the tunnel itself is 3022 feet, the section being circular and 14 feet inside diameter. Both shafts and tunnel were finally lined with concrete not only to provide a smooth conduit for carrying water but also in order

dampness which showed itself on the tunnel roof.

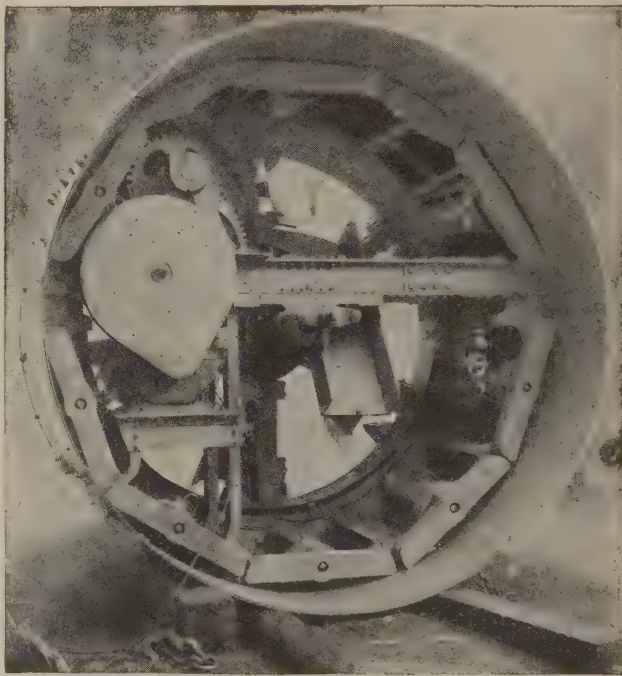
Besides encountering this seam of water, there was an occasional "popping" of rock as the excavation proceeded. Fragments of the solid rock would suddenly shoot from the sides of the tunnel with terrific force, accompanied by a loud explosion, and it became necessary to protect the workmen with steel shields placed around the sides of the tunnel. This popping was explained by geologists as due to the relieving of great pressures which had previously existed in the rock.

The completion of this tunnel was but one of similar feats accomplished in the 92-mile route along which the aqueduct was led. Upon entering New York City, it was found necessary, on account of the great network of pipes and conduits which already filled the city's streets, to distribute the water by means of a tunnel through the bed-rock which everywhere underlies the city. Accordingly, a tunnel was driven for 18.2 miles under the entire length of the city, with its level in some places as much as 750 feet below the streets and nowhere less than 225 feet. Its diameter varies from 11 to 15 feet, and in constructing it twenty-five vertical shafts were driven to tunnel grade, and headings driven from them. Through these shafts provision is made to bring the water to the distributing mains in the city streets, and by natural pressure water can be thrown 260 feet above tide level. This is undoubtedly the longest rock tunnel in the world.

When tunnels are bored from opposite ends, as is commonly done, they generally meet with little error at the center. When the Simplon Tunnel was joined up, the walls corresponded exactly, and the height of the floors showed a difference of 4 inches only. And this in a length of $12\frac{1}{4}$ miles! And yet the rails were 175 feet lower at the southern end than at the northern. Moreover, the length, which could not be measured directly, with mountains towering from 5000 to 7000 feet above, was calculated correctly with an error of only 6 feet 7 inches. When the men working

from both ends of the St. Gothard Tunnel met at the center, the walls differed only by 8 inches and the floors by half that. In the Catskill Tunnel under the Hudson, the center lines of the two headings met with a deviation of but $4\frac{3}{4}$ inches, and in the Hoosac Tunnel with but $\frac{5}{16}$ of an inch. This is accomplished in several different ways. When vertical shafts are sunk, direction may be obtained from plumb lines dropped to the bottom of the shaft. The weights are made to dip into heavy oil in order to counteract the movement due to deflecting currents of air

which rise in the shaft. By dropping two such lines in each shaft, each of which marks a point on the center line of the tunnel, two points on the shaft floor are obtained from which the tunnel line may be run out in either direction by means of transit instruments. These are finely made and firmly mounted telescopes having vertical and horizontal cross-wires inserted in their axis for the



BACK VIEW OF AN AUTOMATIC SHIELD

purpose of sighting on known points or establishing points on the line of sight. By making many repetitions of each observation, a line is run out into the tunnel heading which will deviate but little from the true center line and this is carried forward from time to time as the line lengthens by mounting a transit on its last determined point and sighting back to another as far distant as can be seen. Finely drawn lines on illuminated white backgrounds are often used for "back-sights". After making one, the telescope is reversed through 180 degrees and the line prolonged.

A variation of this method is used in tunnels which are driven without the use of shafts. A well-determined line on the surface of the ground, along the route of the proposed tunnel, is first obtained. Then at the end of the tunnel transit

An exact meeting at the center of the tunnel necessitates only much care and many repeated observations.

Tunneling in rock, although tedious and often dangerous, is a far different thing from boring through soft material,



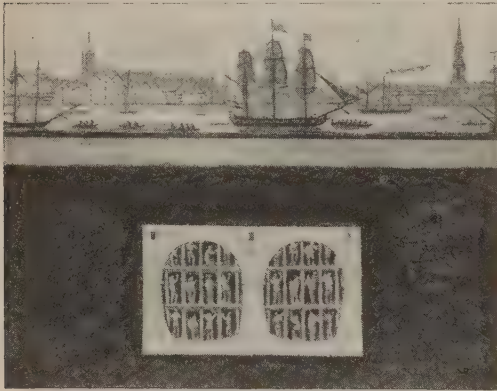
THE SHIELD USED IN THE CONSTRUCTION OF THE ROTHERHITHE TUNNEL

instruments are placed on the center lines, mounted on secure bases. These are backsighted on distant points, previously located on the center line. By a reversal of the telescope through 180 degrees, the line is then carried forward into the tunnel and the headings directed by means of it.

which carries water in large quantities. This is the condition generally met with when tunnels under rivers and harbors are constructed. Under such conditions, it becomes necessary to prevent not only the caving-in of the soft material but the seepage of the water into the workings.

The caving-in is prevented by means of a steel shield which is driven into the heading by powerful hydraulic jacks and within which the men work with comparative security. The leakage is overcome by forcing air into the tunnel under a pressure sufficient to hold back the water. This air pressure is a serious inconvenience, and even menace to the workmen, but it is safe to say that few of the subaqueous tunnels in existence could have been driven without recourse to this method.

The invention of the shield was the work of Brunel, an English engineer, who took out his first patent in 1818. Brunel's shield has been improved in many ways, and more often the name of Greathead is associated with the first shield, although



AN OLD DRAWING OF THE THAMES TUNNEL IN COURSE OF CONSTRUCTION

this famous engineer only improved upon Brunel's original idea. A shield as ordinarily constructed may be thought of as a huge steel cylinder placed on its side and having a diameter approximately that of the tunnel which it is to build. Its forward edge, which is to be forced ahead into the material to be excavated, is equipped with cutting flanges, and its advance is accomplished by means of hydraulic jacks which press against the rear end of the shield and have their bearing against the final cast-iron or concrete lining of the tunnel which is put in place as rapidly as the shield advances. By means of the shield, no part of the excavation is left unsupported, save at the heading, and men may work within the shield excavating the material and loading

it into cars for removal. In short, the shield cuts a clean hole a few inches larger than the tunnel lining, and this hole is immediately filled with an impervious armor of concrete or iron.

Brunel designed and built his first shield for the purpose of tunneling under the Thames. It was composed of thirty-six independent divisions or little cells, within which the men dug away at the face of the soil, throwing it behind them, from whence it was carted away. A depth of three feet in front was excavated at a time, and the shield was moved forward by means of hydraulic jacks. Then the clear opening of three feet left behind was lined with brickwork. A square passage was thus cut and lined with bricks, 37 feet 6 inches wide and 1200 feet long. Within this, two arched tunnels were built, each 14 feet wide by 17 feet high, connected with cross passages at intervals. The tunnel was driven from one end only, and it was eighteen years before it was opened. It is now utilized to connect the systems of the Great Eastern, Southeastern, Metropolitan, and London & Brighton railways. Other similar tunnels under the Thames, of which there are now twelve, reckoning double tubes, have been constructed in about one-fourth the time.

Shields have been used in all, but not Brunel's. The successive accidents and failures and losses of life and long delays due to the irruption of sand and water from the river overhead would not have happened if the employment of compressed air had been understood and adopted. But the time was not ripe for that. The real era of tunnel-making, done with certainty and safety, dates from the invention of the Greathead shield worked together with compressed air. It was first used in England on the Tower Subway in 1869. That was only about 7 feet in diameter. Its first great work was the Blackwell Tunnel, 27 feet in diameter, which was opened in 1897.

In using compressed air, a heavy airtight bulkhead is built across the tunnel as soon as water is encountered. Air under pressure is supplied to the portion between the bulkhead and the heading.

Through the bulkhead must pass the workmen and all the material excavated. This necessitated a device called an "air-lock", which is, in its simplest form, a space or room built into the interior of the bulkhead. This is entered from either side by doors which are capable of being made air-tight. Upon entering the lock, a workman closes the door behind him and the pressure of the air in the lock is raised slowly until it corresponds to that in the tunnel workings. Upon coming out, the process is reversed, but care has to be exercised lest the men come out too quickly. A trouble called "caisson disease" or "bends" often affects workmen under compression, but, save in exceptional cases, it can be overcome by prolonging the period of decompression. Sufferers from the disease complain of great pain in the joints and act as though paralyzed.

The first use of the shield and compressed air in this country was in building the tunnels under the Hudson River by the Hudson River & Manhattan Railroad Company. Work was begun in 1874 by Dewitt C. Haskins, who sunk his shaft on the Jersey shore and started his tunnels through the silt of the river-bed without a shield, using compressed air and canvas linings to hold back the soft material until a masonry lining could be put in place. A disastrous accident in which the river-bed burst in upon the workmen, engulfing them, put an end to this method, and iron plating supported by timbers was used successfully for a distance of 2000 feet. Then financial troubles fell upon the bold Haskins, and in 1888 work was stopped. English financiers became interested and at their request Sir Benjamin Baker visited the tunnel to make an investigation and report. On his recommendation, financial arrangements were completed, and plans for finishing the tunnel by means of a shield and compressed air were perfected. Work was started in 1890 under most adverse circumstances. The tunnel was full of silt and mud and there was a hole 12 feet in diameter right through to the bed of the Hudson River. It was impossible to get beyond the last bulkhead left by Haskins. After trying many expedients,

a device like a plum pudding in a canvas cover, 12 feet in diameter, was put into the hole from above by means of a large floating crane. The door in the bulkhead was then jacked open and the material allowed to leak slowly into the tunnel. This was removed and ultimately it was possible to get by the bulkhead and build a chamber in which to erect the shield. This latter task was most difficult to accomplish, as the plates had to be fitted and riveted, not in a workshop with every appliance available, but in the wet, treacherous end of a 2000-foot tunnel. It is said that the forge fire by which the rivets were heated had a smoke chimney 2 inches in diameter and 2000 feet long, and that the draft was "magnificent". The shield at first gave much trouble by tending to



AT WORK IN THE THAMES TUNNEL IN THE THIRTY-SIX SECTIONS OF BRUNEL'S SHIELD

turn at right angles and cut out for itself a vertical shaft, but finally it was got to going along true lines and nothing happened to stop it until financial troubles again developed in 1891. The work was then suspended, the jacks filled with oil, and everything possible done to leave the work ready for someone to finish. The water was let into the tunnel and there it stayed until 1902, when a new corporation was formed to complete the work. The tunnel was pumped out and after a few alterations in the shield, found intact, progress was resumed. Ledge was encountered and gave much trouble, as blasting ahead of the shield was attended by great danger both to men and shield. Twice the blasts opened the bed of the river and only by dumping scow loads of clay in the hole was the tunnel saved.

The tunnel did not pierce the rock stratum, but only cut into it on the bottom side of the shield and finally a place was reached where the silt above was so soft that it ran like water through the shield-doors. Nothing could stop it until it occurred to the engineers that it might be possible to bake the clayey silt into a hard substance which would not run. Tanks of kerosene under pressure were brought in and flames from blow-pipes were played over the soft clay. After 8 hours of baking, it was found to be hard enough to dig, and work was resumed. Meanwhile, water was played on the shield to prevent damage from the heat. The air pressure at this point was 38 pounds per square inch, making the operation extremely difficult. Seven days later the rock disappeared and sand was reached, through which good progress was made until the shield reached the bulkhead of the short tunnel which had long before been built out from the New York shore. This was March, 1904, thirty years after the first work had started.

This was the predecessor of four tunnels built by the same company under the Hudson. They were really two double tunnels, separately driven. The experience gained in the tunnel just described enabled the work on the others to be pushed rapidly and with comparative ease as long as silt only was encountered. It was found that with the powerful jacks with which the shield was equipped, it was possible to drive through the silt without removing any of the material through the shield, but simply pushing it aside as the shield advanced. Better guidance to the latter was obtained, however, when a small percentage of the silt displaced was allowed to come through the shield, and this was the method thereafter followed. In 1909 the last of the four tunnels was opened and the dream of a half century realized. Since then the Pennsylvania Railroad and other companies have built numerous tunnels under both the Hudson and East rivers, but it is safe to say that even the great difficulties and hardships of all these combined did not surpass those of the first Hudson tunnel.

Tunnels are sometimes constructed in other ways than have been described. In railway subways through cities a "cut and cover" method is often adopted. That is, an open trench is first built in which the completed subway is constructed. All that then remains is to back-fill the trench, and the work is done.

A similar method has been followed in several notable cases when it was desired to tunnel under a river. At Chicago, for example, the double-track street railway at Van Buren Street was carried under the Chicago River by first building coffer-dams across the river and excavating a trench between them. The concrete tunnel proper was then placed in position, the trench filled and coffer-dam removed. At Detroit, a different and very ingenious method was followed in carrying the Michigan Central Railroad tracks through twin tunnels across the Detroit River. Here the tunnel was actually built in sections on the shore and floated out into their proper positions and sunk to the river bed where a trench had been dug by ordinary dredges and piling driven in its bottom. The ends of these sections were afterward connected by divers, and the steel tubes forming the tunnels were embedded in solid concrete placed about them by means of long pipes fed from a floating scow. The whole work called for the highest type of engineering ingenuity and skill.

The Narrows Tube, already under construction and to cost the city of New York sixty millions, linking Brooklyn and Staten Island for passenger and freight service, will have the longest under-water section in the world—about two miles from shore to shore. There are to be two tubes, one for east and the other for west bound traffic. The Richmond end of the tunnel will connect with the city-owned piers at Stapleton and the Baltimore & Ohio Railroad, while the Brooklyn terminus will join with the Fourth Avenue subway and the Long Island Railroad. The longest irrigation works tunnel in the world is under construction in the Cœur d'Alene district of Idaho. It will be 8000 feet long and 2000 feet below the surface.

METHODS OF TUNNEL TRANSPORTATION



STORAGE BATTERY AND TROLLEY ELECTRIC LOCOMOTIVES USED IN THE CATSKILL AQUEDUCT TUNNEL

NATURAL WEALTH IN PRIMITIVE TIMES



IN EARLY DAYS MAN FOUND HIS HEALTH IN THE KINDLY FRUITS OF THE EARTH, AS SHOWN IN HUMBERT'S PICTURE FROM THE WALLS OF THE PANTHEON

THE SOURCES OF WEALTH

The Necessary Parts Played by Land, Capital,
and Labor in the Production of Wealth

THE PROBLEMS OF OUR SAVINGS

THE requisites of wealth-production are, broadly, land, capital and labor. More broadly still they might be defined as land and labor. It is convenient to describe by the term "land" every natural agent — that is to say, not only the soil of a given area, but every gift of nature utilized by man, whether on, in or under the land or sea. It is well to bear clearly in mind that labor is not, as is sometimes loosely said, the only source of wealth. Labor has to be exercised upon the world's natural resources; and those resources are so unevenly distributed as between one country and another, and as between one locality and another, that labor exerted at one place may be very ineffective in wealth-production as compared with labor exerted at another place. It may help clarity of definition if we express our meaning, in other words, by defining "land" as that which owes nothing to labor.

So far as the surface of the earth is concerned, great parts of it have been worked over in minute detail for long periods of time, in some cases for periods stretching back beyond the confines of human history. Year by year, an increasing part of the earth's surface is being brought within the scope of man's civilization. There is perhaps no more wonderful thought connected with an old and developed country like England, or France, or China, than the reflection that almost every acre of it has been in some way scraped, or pared, or cultivated, or mined, or drained, or built upon. Here and there one may find a small spot which has remained undisturbed for a generation or more, but even that

has probably been subjected to cultivation or alteration at some not very remote period.

Land is the source of all our materials, and of all our food. To the agriculturist it is, of course, the prime material. To the industrial captain, it is a fixed base upon which to do certain work, and, in its broader sense, the source of raw materials. To everyone, whatever his calling, it means so much space upon which not only to work but to live. If we inquire what are the distinguishing attributes of land, we find it in the elements of area and location. A certain piece of land is a definite space of the world's surface, the position of which cannot be changed in relation to other pieces of land. We see that these properties are unalterable, and that they inherently attach to land. Whatever else man may do to land, he cannot affect these distinguishing properties. The fertility of land may be increased or decreased. The amount of work to be done upon a certain piece of land may be increased by erecting a building of many floors, multiplying the working space available in respect to it. A definite piece of land, again, may be mined, and minerals brought up for utilization from far below the surface. A swamp or lake may be drained, and what was water-surface converted into more useful land-surface. These and many other things can be done by way of changing the character of land and the use of land. Through them all, however, it will be seen upon consideration that the unalterable qualities of area, or extension, and of situation remain.

Area and situation of land of primary importance in all nations' economy

It is of great importance to recognize this fact in relation to the wealth or well-being of a nation. The peculiar characteristics of land make it of primary importance in a nation's economy, whatever the condition of its development.

In an agricultural country, of course, the land is not only the living-place but the work-place of the entire community. We have seen in former chapters that with the progress of science it becomes possible to produce the food for many people by the labor of a few. That means the constant and increasing transition of labor from agricultural to industrial pursuits; and for such laborers as are thus translated the land ceases to be a work-place, save in the sense that upon a certain area a man exercises some industrial art. In this respect, land plays a comparatively small part; even a large factory needs but a very small area of land for the conduct of its operations. Several hundreds of men can work upon a large plant erected upon the several floors of a factory which may not occupy more than a quarter of an acre. All the factories of the United States, if gathered together into one place, would occupy an insignificant part of the national area. Although this is the case, however, land does not cease to be important to those engaged in industry. The growth of industry means the growth of towns; and the industrial revolution which characterized the nineteenth century crowded more than half of the entire population of the United States into urban areas.

Our slow loss of the habit of huddling together in towns

Whatever the work in which man is engaged, he needs, if not land upon which to grow food, at least space upon which to live in health, and upon which he and his family may exercise and disport themselves. To the urban dweller, the inherent and indestructible quality of land — space — becomes of greatly added importance.

Time was when a number of causes restricted the size of towns. The first of these was the need for mutual protection, and the second was the limitation of the means of locomotion. Both these causes have become obsolete.

We have now the means to arrange our towns in wide areas, with a wealth of those gardens and open spaces without which it is impossible for human beings to retain their health and vigor. It is now easily possible for a nation to turn its towns into health resorts, combining every natural gift and amenity associated with rural life, with all those qualities of near association and communal life which are the essential attractions of a town. Town making and maintenance in all its branches is really the main industry of such a nation as ours. It is a great pity that this is not realized, and that we do not elevate it to a supreme art. If we did so, and if we concentrated upon it the best of our intelligence, we should so greatly add to national well-being as to transform society.

It will be perceived that as time passes, and as land is worked upon by the hand of man, the gifts of nature as expressed in land become commingled more or less inextricably with the results of labor. This is true of both rural and urban land. A farm is not merely a piece of land; it is a manufactured article, and if it is a good and efficient farm it is a very highly manufactured article. In some cases a farm exists where once was a mere swamp, or where impenetrable forests were situated. An irrigated farm in the far West is the result of reclamation of area which at one time had none of the qualities of cultivable land. When we turn to urban land, we are again confronted with what is a manufactured article. The cost of making urban roads and pavements, and of furnishing them with proper sewers, water-pipes, etc., is exceedingly heavy, varying, of course, with the size of the plots which are reserved for human habitation. Even if houses are built only four or six to the acre, the cost of making the appropriate roads, pavings, sewers, etc., amounts to a thousand dollars or more per acre.

The difficulty in dividing rent between natural gifts and interest on capital

Thus, what is commonly called the "rent" of either rural or urban land includes not only the *rent in its strictly economic sense of payment for natural gifts in fertility or situation, but interest on the capital which has been sunk in making or maintaining the farm or urban land.* "Rent" in its ordinarily used sense is not true rent as the economist defines it; and in practice it is very difficult to distinguish true rent from what is ordinarily called "rent". In relation to an ordinary farm, for example, how difficult it is to decide what part of the annual sum paid for its use is paid for its natural qualities and situation, and what part for the artificial things—the buildings, fences, ditches, etc.—which make it a farm. It is easier to distinguish true rent in the case of an urban site, for there we are able to estimate closely what the building or other improvement is worth, and therefore to value the essential and distinguishing situation for which an annual sum is paid, which is truly rent.

The natural rise in the value of land because of its limited amount

Land is obviously limited in extent. The land area of the world amounts to only about one-fourth of the entire surface of our not very large globe. Land is thus a commodity of which there is a distinctly limited supply. As the population of a country grows, the land remains the same in area. Every addition to the population, other things remaining the same, raises the degree of use to which the land of a country is put, and therefore increases its value. Consequently, in a growing country, the value of land and the rent of land must grow, and the owners of land must be able to secure an increased income from it. Great political and social problems thus naturally arise in connection with the forms of its ownership or tenure; and in all the countries of the world these problems are being worked out with very great difficulty and in many different ways.

We pass from land—from the gifts of nature—to the labor which, intelligently exerted upon natural gifts, produces material wealth. We picture man in his primitive condition ruling over what were practically unlimited quantities of land, and, by the aid of a few very simple arts, wringing from great natural wealth a bare subsistence.

Natural wealth only yields its stores to intelligent labor

We are reminded here that, just as it is true that labor alone is not the source of wealth, so it is true that a great and bountiful natural store of wealth may be used but little, and yield a scarcity of material wealth to unintelligent labor. Time was when the extraordinarily wealthy areas of the United States and of Canada were the happy hunting-ground of peoples who knew not how to employ the natural abundance which encompassed them. We must recognize that they obtained freely the means of physical health and development, but they were only able to do this because they were few in number. Land was to them unlimited, and the chase, combined with rude forms of cultivation, yielded them in ordinary times a sufficiency of food. Even in such a primitive form of life, however, we see the beginnings of those storings of the fruit of labor which we call "capital". The Indian who spent a day, or days, in fashioning a weapon with which to hunt was engaged in storing labor for the purpose of securing more wealth with less labor. Every hour's work spent or stored in fashioning a weapon or an implement meant the saving of many subsequent hours in the pursuit of wealth.

Presently, as man progressed in civilization, he began to domesticate certain animals, and flocks and herds became the chief expression of the wealth of families or tribes. As cultivation became better understood, cultivated land became an expression of saved or stored labor. In cold countries man had, from the earliest days, to spend and store labor in the form of rude clothing, and of huts or other habitations.

The growth of stored labor, or capital, through the power of machinery

So gradually there grew, from age to age, the stores of wealth of material things which are an expression of the intelligence of men in spending the labor of the present to provide for the known and anticipated needs of the future.

In modern times, beginning, as we have seen, with the middle of the eighteenth century, capital or *stored labor* began to assume a new and gradually increasing importance. The age of mechanical power began, and in the first half of the twentieth century that age is still young. We have come to learn that by spending a considerable amount of labor upon the construction of machines we can, with the aid of those machines, multiply human effort a hundred- or a thousand-fold, and, in effect, turn the labor of 100,000,000 of people into the effect of the labor of thousands of millions. Perhaps we should not say "we have learned", for it is very doubtful whether this truth is realized in all its fullness by more than a fraction of our people, and most certainly the powers that we possess are not fully exercised.

In modern production capital has assumed complete supremacy over land

The progress of science and machine-production has elevated capital into an entire supremacy over land as a factor of production. Before the industrial era, land and labor and a very little capital sufficed for the operations of mankind. Today, large amounts of capital are necessary for the conduct of every business. Even the farmer who took up, *without payment or rent*, a quarter-section (160 acres) on the Western prairie—the natural fertility of which was so great as to yield abundant crops for many years without manuring—needed several hundreds of dollars' worth of capital to equip himself with the necessary appliances. As for industry, what a contrast obtains between, say, the old textile operations, with their simple spinning-wheels and hand-loom, and the modern textile mill, with its intricate and costly machinery!

Textile operatives are still cheaply housed, but each unit works with a plant of great value. In a modern cotton-mill, the amount of capital employed for each operative amounts to \$2500 or \$3000.

Essentially we see that the store or stock which we call "capital" consists of putting by the fruits of labor in forms of some permanence; but, of course, real permanence does not attach to anything that man can store, save to a few of the metals. *The storing of capital means, therefore, not only the saving of it, but the preservation and guarding of it.* If the capital stock is saved in the form of a building, the building must be constantly repaired and protected from the effects of the atmosphere. If man takes his hand from the building which he has made, a process of deterioration immediately sets in. If the storage takes the form of a machine, the machine must be constantly cleaned and oiled, whether in use or not. If the store be grain, then expensive arrangements must be made for its preservation for even a limited period; while many forms of food can be stored for only a very restricted period indeed. This expenditure of labor upon maintaining capital is often overlooked. Consideration will show that it follows from it that when capital is lent by A to B, B has not only to pay A positive interest on the sum lent, but to maintain the capital lent, which is the equivalent of a sum which we may call "negative interest". This may be clearly illustrated by the case of a man who owns two houses, but who only wishes to occupy one of them. If he desires to maintain the value of his second house, he must employ a competent caretaker to keep it clean and in good order, and that, of course, is a matter of considerable expense. If, on the other hand, he lets the house, he gets, in addition to the rent which is paid, the care and cleaning of his house for nothing. It is obvious, therefore, that the real interest which he receives is not merely the sum which is agreed upon in the lease, but the value of the care and cleaning of the house, for, if he had no tenant, he would have to employ caretaker and cleaner.

A simple illustration of what the storing of capital really means

Thus it is with all capital. In an illustration which Bastiat employed to illustrate interest, he pictured a workman, possessing two planes, lending one of the planes to a second workman, and the second workman, in return, paying the first part of the extra produce which was the result of the employment of the plane. Thus, Bastiat showed that although the second workman paid interest to the first, he really gained, because the use of the plane enabled him to do more work than would otherwise have been the case; that is, after paying interest for the plane the second workman was better off than if he had not paid interest. This, however, does not cover all the considerations involved, for it will be seen that the practice of interest involves not only the payment of part of the produce of the capital lent, but the preservation of the capital intact and undiminished (*i.e.*, the plane is assumed never to wear out). At least, that is what happens in some cases, and it is what the investor hopes for in every case. As a matter of fact, we know that very often capital lent is entirely dissipated in fruitless endeavor, and that the investor obtains neither interest nor the preservation of his capital.

Self-denial as well as intelligence needed to rightly store capital

It demands not only intelligence but self-denial to store the fruits of labor. Interest has been sometimes defined as a reward of abstinence. That, of course, it certainly was in the preliminary stages of capital accumulation, and that is how saving presents itself even today to the man of small and moderate means. It requires no little abstinence for the man with \$20 or \$30 a week to put by any proportion of his earnings, however small. But the greater amount of saving today is done by persons who already have incomes large enough to command much more than the necessities of life, and it is not very appropriate to regard their further accumulations as "abstinence".

Saving by the prosperous more properly "time preference" than "abstinence"

The difficulty, however, is with the word "abstinence", and especially with the self-denial or parsimony which it suggests. A better word is "waiting", and some economists use the term "time preference". The fundamental principle involved is very simple. No one, whether rich or poor, can "have his cake and eat it, too". We are always confronted by the alternative of spending today or saving for tomorrow.

Some men natural-born savers

It is likely that much money would be saved, much capital accumulated, even if no interest, or a very low rate of interest, were paid. Some men are so constituted that they really find more pleasure in keeping and in accumulating than in the present consumption of things. The miser is merely an extreme case of the type of man in whom what J. S. Mill called the "effective desire of accumulation" is strongly developed. But fortunately or unfortunately the men who, on any terms, would rather save than spend are rare.

The wise man who in his earning years provides for his old age or his family

But there are many men who, even if interest did not exist, would save in order to provide for their families, for their own old age, or to insure against the loss of earning power resulting from sickness or accident. The wise man, the man who plans his life rationally, looks into the future, and even if he cannot hope to hand any considerable estate on to his heirs, he will be able, if he plans carefully, to equalize his expenditures and his income through his years of life. After middle life, very likely, his earning capacity may be lessened. In old age, he may become unable to earn an income. Therefore, unless he wishes to be dependent upon the bounty of others, he will save, even if interest on his savings is not held out to him as a further price or inducement for saving.

Other motives necessary to supply the capital needed by a modern community

It is very certain, however, that motives of the kind we have discussed would not suffice to supply the modern community with all the capital it needs. The proof of that simple statement is found in the fact that men are willing to pay a price for saving, and it is fair to assume that the price is no higher than it need be to induce the necessary amount of saving.

Many men have to be induced to save, or to save more than they otherwise would. The fact is that more of us, given the choice between a dollar today and a dollar a year from today, will without much hesitation take the dollar today. To some extent this general preference for present rather than future wealth—a preference which stands in the way of capital accumulation—is irrational. It is highly developed among savage tribes, who are wont to alternate between periods of feasting and surfeiting and periods of famine. Regard for the interests of the future has developed as the rational element in man has developed. It remains unfortunately true, however, that many men are too short-sighted, too much obsessed by the interests and pleasures of the moment, to give the future its reasonable and rightful due. At one social extreme is the miser, at the other is the spendthrift.

The additional saving to be obtained generally by a moderate interest premium

No price or premium in the form of interest however high would suffice to induce all men to save, but society has found by experience that a fairly moderate price or interest premium will suffice to induce enough additional saving (over and above the saving that would be made if no interest were paid) to replenish, maintain and slowly to increase society's stock of capital. The man who would refuse to exchange a dollar today for a dollar a year from today might be willing to give a dollar today for a dollar and five cents a year from today.

Although at various points in this chapter and elsewhere we have referred to capital as the product of labor, this is merely to distinguish capital from land, which in its original state is not a "product" at all, but is given by nature. The fact is, as we have seen, that capital requires for its production both labor *and* waiting. Capital is saved labor, or rather, it is the saved product of labor, and the word "saved" is quite as important as the word "labor". Of course any particular bit of capital, like a machine or factory building, or a ton of coal, may be viewed as the product of labor, land and capital, as well as of waiting, but the capital that is used in the production of new capital is itself the product of factors that lie yet further back in the productive series. If we push our analysis remorselessly back to the origins of economic life, we must find that there are three, and only three, original factors or elements in the production of wealth. Those three original factors are nature (land), labor and waiting.

Our need of larger capital for purposes of social life and economic production

As to the quantity of capital employed, we gave reasons in the last chapter for believing that although the accumulations of the United States are actually great, they are relatively small when the enormous size of our population is concerned. We need a larger capital than is at present employed, both as to the framework of social life and for the purposes of economic production. If, for example, we consider the grave and great matter of the private houses and public buildings of the community, with their necessary complement of developed connections in the shape of properly made roads and streets, with all their furnishings in connection with lighting, draining, etc., an enormous amount of capital is called for if a hundred millions and more of people are to be housed with due regard to the maintenance of perfect health, and if they are to enjoy such a standard of comfort as we should desire for every man after so many centuries of development, and in view of known and proved inventions.

The high cost of living decently shows inadequacy of capital applied to it

If we take 100,000,000 people as a fair number to represent 20,000,000 families, and if we assume that to provide them with proper amenities costs no more than \$5000 per family, apart from the value of any land used, then these things alone would, it will be seen, demand the use and maintenance of \$100,000,000,000 of capital. If this is compared with the valuation of existing capital given in an earlier chapter it will be realized how inadequate is the amount of capital yet applied to this, the primary need of a civilized community. As a matter of fact, even \$5000 does not go very far in providing town housing of first-class type, in which the best materials and workmanship are employed.

The fact is that our conceptions of what is possible, in connection with the economic use of capital, have not yet developed very far. The greater number of people come to look upon life as a thing which, in the mass, must necessarily be mean and sordid. The average conception, it is to be feared, is of a great mass of people living at a low scale of existence, in which a limited number of them may enjoy a considerable amount of comfort. Society is visualized as a body of individuals in which a certain proportion of them may, by luck or judgment, or both, rise out of the mass into a condition of superiority and decency.

Casual saving and the lack of a specific national purpose in accumulation

As things are, the country is supplied with capital for the various purposes of social life, trade and industry, as it were, casually. There is no set purpose in saving; there is no specific national or social aim in accumulation. The thing resolves itself seemingly into a more or less spasmodic and chance investment by various individuals, who spend and invest upon no fixed principle, and whose sole object, of course, is individual gain. No one surveys the country as a whole, and forms an estimate of what capital stock is needed to render the labor of its people more productive. There is absolutely no means of

organizing capital-saving. It is often questioned whether this plan, or lack of plan, can forever continue to be regarded as satisfactory by an intelligent and advanced people. The proper use of capital, of stored labor — of, in the words of J. S. Mill, the “accumulated stock of the produce of labor” — is essential. If labor is to be economically exercised, it must be put forth in connection with the use of the best-known appliances that have been devised by the genius of man. Any labor which is not so applied is wasted in some degree.

Difficulties in the way of a practical substitute for planless accumulation

The difficulty is, however, that there seems to be no really practical substitute for this apparently planless system of capital accumulation. There are some socialists, of course, who teach that the interest on capital is always unearned; that it represents nothing more than the exploitation of the laborer. We cannot accept this view, for reasons which will be made clear presently. Capital — properly utilized — is productive in just the same way that labor — properly utilized — is productive. Even in a socialistic state, with all industries the property of the government, capital accumulation would nevertheless be necessary and interest would still exist, although it might be hidden or disguised in one way or another. A socialistic state could not repair, maintain, replace and increase its railways, its industrial plants and its distributing establishments without saving, that is, without storing up labor. Labor which might otherwise have been utilized in providing for the satisfaction of immediate wants must, even in the socialistic state, be turned aside or diverted. Some labor must be assigned the task of maintaining and increasing the capital equipment of the nation. This labor produces no immediately consumable good; its benefits will come to fruition only in the future. But in the meanwhile the laborers must be fed, and clothed and housed. In some way or other, *advances* must be made them.

No form of social organization can eliminate the sacrifice of waiting

In the socialistic state, therefore, there must be savings. The community as a whole must *wait* for the final product of much of its work. The sacrifice of waiting, or the postponement of consumption, cannot be eliminated by any possible form of social organization. In our present competitive society waiting is a matter of free contract. Some men agree to save and wait and are paid a price for waiting. In the socialistic state, waiting might be enforced by means of taxes, the proceeds of the taxes being used in maintaining and increasing the nation's capital. Or some other device might be used. The essential thing is that waiting would be compulsory. It would be a matter of law, of national decision, rather than a matter of free agreement.

Of course just so far as public expenditures are today made for permanent public works there may be said to be a degree of compulsory "waiting". In general, however, most of our capital supplies come through free contract. Now, the method of free contract has its disadvantages. It appears, as has been said, planless. But the planlessness is in part only apparent. We must remember that the direction which the investment of capital takes is really determined by the estimates which business men make of the varieties and kinds of things consumers will demand. The investment of capital today, so far as it is successful, is really governed or controlled by the community as a whole through the community's demand for the products of capital. In a way, the community "votes" that such and such things will be produced and that capital shall be created in such and such forms. But the ballots the community uses in this voting are the dollars which the community spends for consumable goods.

In this kind of voting, the individual voter's power is measured by the number of dollars he has. The wealthy man has a disproportionate influence. There are undoubted evils and obvious waste in the system. Their cure, however, is in the

general extension of higher education in the community and in the equalizing of opportunity, rather than in introducing a new system of control which would be based upon political votes in place of "dollar votes".

One very important, but frequently neglected element in the accumulation of capital is the retention and reinvestment of business profits. As a matter of fact, the line between principal and interest is more or less arbitrary. When the business man or investor only gets his money back, we say merely that the principal of the money has been returned, and we see nothing in the phenomenon that gives rise to any peculiar economic or social problem. But when he, in addition to his principal, gets 5 or 10 per cent more, we discover the "problem of interest". Now, anyone who can give a satisfactory explanation of just how the organization of economic life makes it possible for the business man to get back 100 per cent, should be able to explain how it is possible for him to get back 105 or 110 per cent on his investment. There is no essential difference between one problem and the other.

We have been careful throughout this discussion to treat the repair, maintenance and replacement of capital goods as ways of investing capital. As a matter of fact, they are. Capital is not created once for all. Saving is a continuous and really perpetual process. There is nothing except business prudence to prevent the storekeeper from gradually selling his stock of goods without replacing it, pocketing not merely the "profits", but also re-pocketing the principal of his investment. There is nothing to prevent the manufacturer from wearing out his machinery or from using up his stock of raw materials without replacing it. The ordinary maintenance of the national stock of capital is, in practice, so largely a routine matter, so largely an accepted business practice, that it goes on, for the most part, silently and efficiently. And yet the largest part of the nation's annual investment of capital consists of just such replacement of older stocks.

In addition to the replacement of existing capital, prudent business men are accustomed from time to time to put part of their earnings "back into the business". Professor David Friday estimates that of the enormous profits made by American corporations during the Great War and the years immediately following, not over one-third have got into the hands of the stockholders, and that third, he says, was subject to the heavy surtaxes imposed by the government on personal incomes.

"A substantial portion of what the stockholder had left went to furnish the great body of the investment funds of the country. It is no exaggeration to say that not more than one-fourth, and probably not more than one-fifth, of the whole volume of corporate profits was actually spent by the stockholders of these concerns. The other 80 per cent went for taxes, for loans to finance the war and to furnish the funds for industrial expansion."

All together, Professor Friday estimates, business corporations in the United States, in the 11 years from 1909-1919, turned back from their profits about \$23,000,000,000, this sum constituting a net increase in the invested capital of the country. Similar practices, of course, were not only common but habitual among individual business men and farmers. Everyone at all familiar with American agriculture realizes the extent to which the American farmer puts the year's surplus back into the improvement of his farm. His profit is in the increase of his capital.

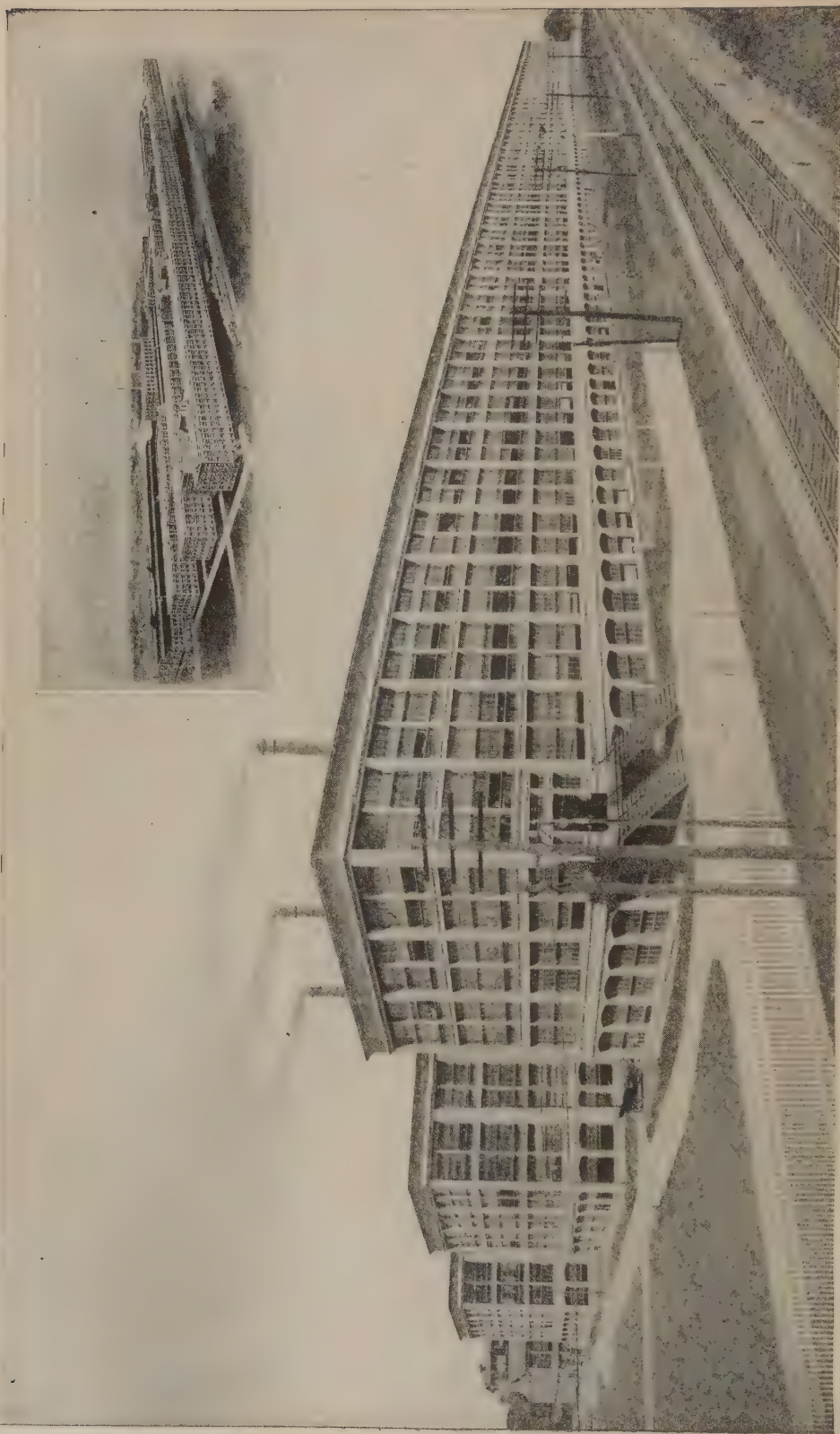
The reader should note that a large part, unquestionably the largest part, of modern savings comes, not from investors or capitalists "living on their incomes", but is caught, turned aside as it were, in the active process of modern business. Private property in capital is the condition of and a stimulus to the saving done by the modern community. Private property undoubtedly has its abuses, but thus far no one has been able to show clearly how we are to have the enormous advantages of the productive power of large masses of capital without the stimulus and the safeguards which the rights of private property give.

From one point of view, of course, a nation's real capital does not consist so much of buildings, machines, railways and the like, as of the industrial and technical knowledge which the members of the community possess, handed down from generation to generation, diffused by education and increased by the advances of science. Our knowledge and our science are infinitely more precious possessions than the whole aggregate of our accumulated capital. Destroy our material accumulations and in a generation they will have been replaced. Destroy our knowledge, annihilate our science, and man, reduced to the intellectual status of the savage, would not even know how to use the tools which he has made for himself.

Science teaches how to harness nature, and to use her powers for our own needs. For a short time, the advance of scientific knowledge may be "capitalized" in the form of valuable technical secrets, or in patent rights, but, in the long run, scientific knowledge, of whatever sort, becomes diffused. We pay no rent, interest or royalty to science as such. We merely have to pay for the technical equipment, for the capital, which is required if we are to make effective use of our accumulated fund of scientific knowledge. Appraised by his real contributions to wealth and welfare, not in dollars and cents, the scientist may easily outrank the millionaire or the captain of industry. His contributions to society's capital are, in general, free. For that reason, they do not fall under the ordinary laws of supply and demand. There is no limitation of supply; there is no question of a larger or a smaller number of increments of supply. The scientist's contribution is, or becomes, a free good. Just because it is diffused and free, its *apparent* utility to society may be less. Ordinary capital, in order to have value, must have both utility (productivity) and scarcity. The scientist's contribution has productivity without scarcity.

But that certainly gives us no reason for excluding it from its rightful position as the most important single element in the "social capital" of the day.

WHERE THE WORLD'S SHOE MACHINERY IS MANUFACTURED



FACTORY OF THE UNITED SHOE MACHINERY CO., BEVERLY, MASS.
This concern supplies nearly all the machinery for the shoe manufactures of the civilized world.

SCIENCE AND SHOE MAKING

The Inventions Which Led to a
Revolution in this Important Industry

RISE OF THE AMERICAN BOOT AND SHOE TRADE

IN most trades of the present day wonderful advances in manufacture have been achieved by abolishing all the old rules-of-thumb, and calling in men of science to discover more exact, surer and more effective methods. In the leather industry, however, we have not yet succeeded in equaling the results of the slow, primitive methods of tanning practised four thousand years ago. Modern science has apparently failed to justify the hopes of the most enlightened of tanners. It is true that modern machinery and modern tanneries are able to produce in fairly cheap abundance the leather goods that serve the immediate needs of the people. Things like boots and shoes and gloves, which are worn out and thrown aside, have become greatly cheapened by scientific methods of manufacture. But, in spite of all the appearance of progress, much of the presumably fine leather supplied to craftsmen in the bookbinding and furniture trades is deplorable. Some of it decays in so short a period as five years. The fact is that a good deal of the leather made since 1830 is bad, and most leathers have got worse since 1860. Practically all Russia leather bindings made during the last fifty years are rotting away; and so are those of morocco leather. Hardly any good, sound calf has been made for eighty years. Ten years of life is the limit for many modern cheap leathers. Some of it loses its color when exposed just for a week to summer sunshine. It is extremely doubtful if any of the work of the famous craftsmen in leather of our days will be known to future generations, for most of it is already fast perishing away.

Such is the definite and authoritative verdict arrived at by well-known men of science who have themselves been long and intimately connected with the leather industry. Some of these men have taken a highly important part in inventing and developing new methods of converting the perishable skins of animals into a firm, flexible, and lasting fabric. It is now fairly well known what takes place when a skin is made into leather. The under skin is the part used by the tanner. It consists of the extremely perishable substance of gelatine.

The problem of leather-making lies in discovering some matter which will combine with the gelatine fibers and preserve their flexibility, while making them strong and durable. There are three old ways of doing this. In the most primitive method oils or fats are rubbed into the skin, transforming it into a material as soft at times as fine cloth, and yet extraordinarily durable. This is the way of making chamois leather. Very likely it was known in the Stone Age, and many savages of the present day use it in an admirable manner. When, for instance, a young Zulu desires to marry a woman of his tribe, he has to make a leather robe for her with his own hands. And he dresses the skin of a large beast, now usually a cow, until he converts it into a beautifully soft and exquisite material as pleasant to the touch as the finest and most delicate of cloths. None of the products of our modern scientific tanneries can compare with this work of a savage.

It was also the savage — possibly some Egyptian of the New Stone Age — who discovered the method of tanning leather.

INCLUDING MANUFACTURING, ENGINEERING, TRANSIT AND EXCAVATION

This is done by working into the gelatine fibers of the skin the tannin obtained from the bark or seeds or leaves of various trees and shrubs. In all probability the discovery was made accidentally while trying to dye the skin by some vegetable matter. Color was the thing aimed at, and the marvelously preservative effects of tannin were achieved by chance. The astringent bark effected a permanent change in the texture of a skin; it kept it supple; it increased its strength, and it stopped decay. An Egyptian granite carving, probably at least four thousand years old, is preserved in the Berlin Museum in which leather-dressers are represented. One is taking a tiger skin from a tan-pit; a second is employed in another tub; while the third is working a skin upon the table.



These three processes of chamoising, tanning and tawing leather remained in universal use until about 1884. No improvement in the general methods of preparing leather took place from the primitive ages until about 1790, when the use of lime, to loosen the hair from the skin, was introduced. A few years afterwards Sir Humphry Davy apparently proved the fact that the process of tanning was a chemical art, and as such should be conducted with scientific methods. So ingenious men began to devise various ways of quickening the slow processes that tanners had used for thousands of years; and good leather gradually ceased to be produced. In about half a century from Davy's time the chemist had cheapened leather by destroying its most valuable qualities.



REMOVING THE HAIR FROM THE LIMED SKINS BY HAND AND MACHINERY

Embossed and gilt leather straps are found on some ancient mummies; and an Egyptian boat-cover of embossed goat's leather, as well as shoes of dyed and painted morocco, are still in fairly good preservation. In China specimens of leather have been discovered in company with other relics that show them to be perhaps the oldest products of antiquity extant.

Among the Romans the third process of leather-making was practised. In this method a chemical is employed—alum. The process is now known as tawing, and it is used in the manufacture of white leather. The skins of kids and calves and lambs and sheep are tawed with alum and salt, and are then made into the upper part of kid boots and the material of gloves.

The plain fact of the matter is that the men of science were wanting in knowledge. What they regarded as a fairly simple matter of chemical calculation was really a problem which was then quite beyond their powers of solving. It was largely connected with the mysterious processes of living matter. The microbe, not then suspected, much less discovered, often took an important part in helping the tanner to transform a decaying skin into a lasting piece of leather. Moreover, the matter involved the chemistry of complex living compounds, the physics of solution and of the structure of gelatinous bodies — all of which are high and difficult provinces of knowledge that have not yet been fully conquered by science.

THE CONVERSION OF PERISHABLE SKINS INTO LASTING LEATHER BY CHEMICALS

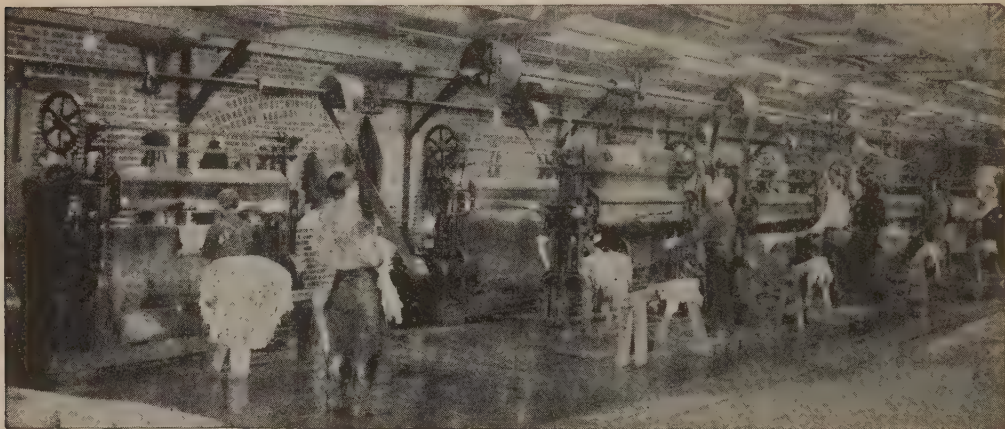


THE TUMBLERS AND PADDLE-WHEEL VATS IN WHICH SKINS ARE IMPREGNATED WITH SALTS AND ACIDS IN THE CHROME TANNING PROCESS

This is why we began by saying that the present position of affairs in the leather industry was very curious and very interesting. The tanner has not received from men of science in the last hundred years the help that Sir Humphry Davy rather rashly promised. In the highest reaches of the tanner's craft, modern science has been somewhat of a will-o'-the-wisp, that has led him from the old, winding, and yet safe road, and landed him in a slough. Yet so many obstacles now prevent him from returning to the ancient track that he is compelled to trust in science to guide him further on his way. So chemist and bacteriologist and physicist are now busy endeavoring to help him. Already the invi-

a German chemist, clearly described a method of tanning leather by the action of salts of chromium, but by an extraordinary oversight he did not recognize the practical value of his discovery. He thought that the leather so produced would be greatly injured by water. It was as though a man discovered a mine of diamonds and threw the stones away, thinking they were worthless pebbles.

A similar thing happened in England some years afterwards. The late Professor Hummel was asked to dye a piece of chrome leather that was a very ugly color. In accomplishing this task, he discovered a new chemical tannage and produced a piece of excellent leather that still remains,



THE STRIKING-OUT MACHINES, THAT STRETCH AND SMOOTH THE GRAIN OF THE TANNED SKINS

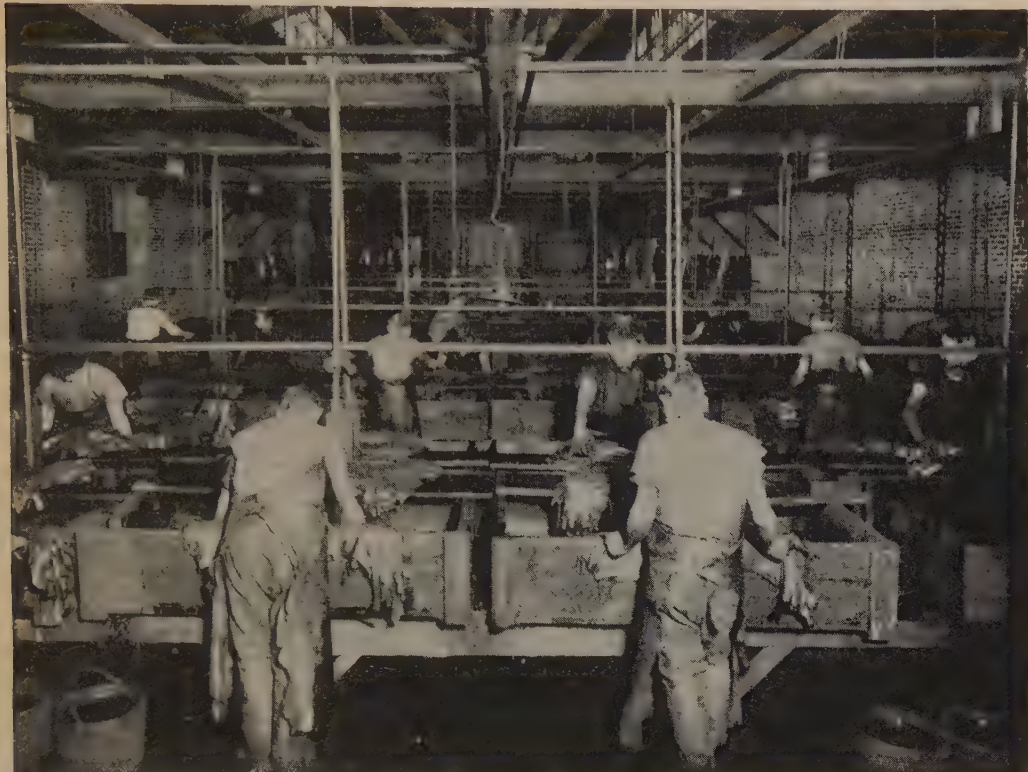
ble microbes that he used to use without knowing he was using them are being cultivated in a pure state and sent to him in bottles, so that he can employ them, measured and under scientific control, in his tanyard. Biologists are examining deeply into the wonderful structure of living matter, and especially into the action of organic membranes, and they are making such progress that they will soon be able to tell the bewildered tanner exactly what happens when he combines tannic acid with the gelatine of the stripped skin.

But it is the chemist who is foremost in helping the distracted leather-maker. This is only fair, because it was he who induced the poor man to abandon his slow but sure, primitive but effectual, methods. As early as 1856 Friedrich Ludwig Knapp,

in perfectly sound condition, in the possession of the Yorkshire College at Leeds. But as there was no legal publication of his invention, room was left for a later inventor to rediscover the means of producing a vast revolution in the leather industry. This was done in the United States in 1884. The result was a rapid development that enabled America to lead the whole civilized world in the leather trade.

Yet here again the event took place in an accidental way. A chemist employed by a New York firm of coal-tar color merchants was asked by a friend if it were possible to produce a leather for covering corset-steels which would not rust the metal as did leathers prepared with alum.

COLORING AND OILING THE TANNED SKINS



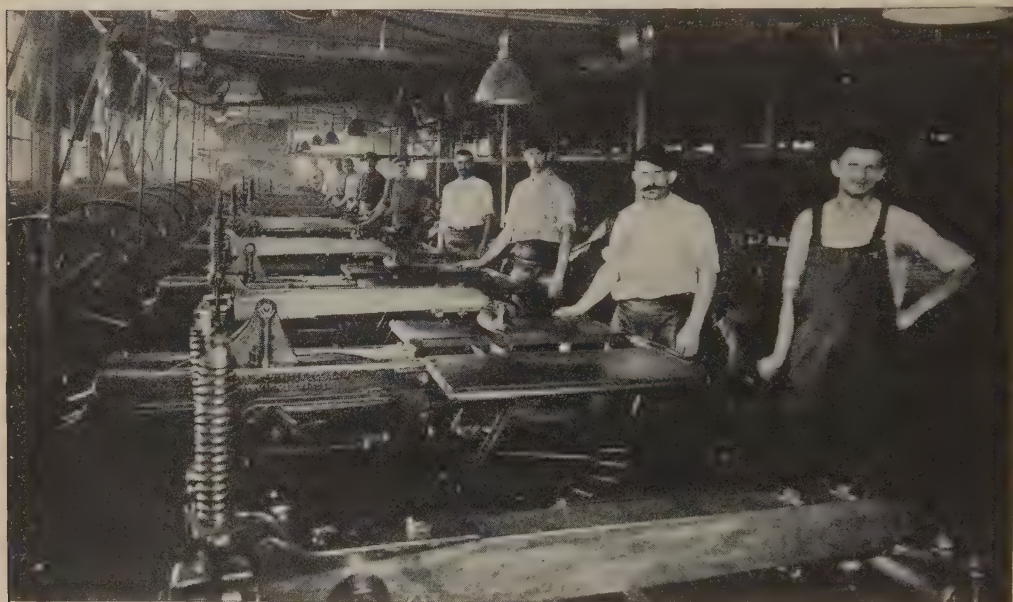
THE OPERATION OF COLORING THE TANNED SKINS BY MEANS OF DYES



INCREASING THE STRENGTH AND PLIABILITY OF LEATHER BY WORKING OIL INTO THE SKINS

Augustus Schultz, the chemist in question, knew nothing whatever about tanning processes. His happy ignorance prevented him from distrusting the evidence of his eyes. Instead of being—like Knapp and Hummel—overborne by a wide and intimate knowledge of the gaps and defects of chemical science in relation to leather-making, Schultz brought to the problem the enthusiasm excited by the new coal-tar industries. He took a chrome preparation used in making wool ready to receive an aniline dye. He treated a skin with this chrome preparation, and then put the skin in a bath of the “hypo” that

chemists of America had far-reaching consequence on glazed kid, box and willow calf, and on the belting and harness leather industries. The French tanners of light leathers were ruined, and the Americans captured the best of the world's glazed kid trade. The only respect in which the foreign manufacturers could in any way compete was in the old-fashioned tanning of strong, heavy skins for the soles of boots. They could not hope in other grades to overcome the advantages the American manufacturer had gained through his control of the new patented tanning processes.



Courtesy Endicott Johnson Co.

STAKING MACHINES FOR SOFTENING AND TAKING THE STRETCH OUT OF LEATHER

photographers use, and lo and behold the trick was done. Quickly the marvelous importance of chrome tanning was perceived in the United States. Many other American inventors at once set themselves to work out variations of the new chemical tannage, and a powerful trust arose that acquired most of the patents.

Chrome leather, far from being less resistant to water than bark-tanned skins, proved to be wonderfully strong. It was much stronger than any other leather. It could stand boiling water, that destroyed all skins prepared with alum or vegetable tans. The achievement of the technical

Not only did the American possess a surprisingly cheap and rapid method of scientific tannage, but he had worked out a set of extraordinary machines for making boots and shoes out of the new leather. Long before the invention of chrome leather, he had transformed, with remarkable ingenuity, the ancient craft of the bootmaker and shoemaker into a mechanical industry. It was he who developed a method of providing the poorest workers of the civilized world with cheap and good boots and shoes. Three hundred years ago, when shoemaking became a real art-craft, and the shoemaker pro-

duced beautiful works in leather and satin, which for soundness of design and beauty of shape have seldom been equaled and never surpassed, the common people profited but little by the perfection then attained. For we can still see by the pictures and etchings of the time that a large proportion of the peasantry went barefoot. What they suffered from chills and rheumatic complaints and other disabling diseases is not easily estimated. Certainly

ing in use in recent years in remote parts of Ireland. It resembled the moccasin of the Indian. But in spite of brogues and wooden shoes a considerable number of civilized people went without foot coverings, until machinery began to be employed in making good and cheap shoes.

The first piece of shoe machinery, a lasting and soling machine, was made in England a hundred years ago. The English also invented a rolling-machine that



A CORNER OF THE DRYING-ROOM FOR STAKED SKINS

the want of good boots was one of the causes of the general shortening of life among the working people in the damp and variable climate of Northern Europe. Some of them, it is true, were able to afford wooden shoes, which, stuffed with straw, kept their feet clear of the wet earth; and there were others that wore a foot covering of heavy leather, roughly put together and stuffed with hay. This was the brogue worn by the ancient Britons, and surviv-

cheapened sole leather, by compressing it in a minute and saving hours of pounding. This occurred in the middle of the nineteenth century, but after that date the American inventor swept everything before him. Having made a sewing-machine, he adapted it in various ways to the quick and sound manufacture of boots and shoes, and soon other labor-saving devices were worked out in a practical way in the United States, and applied in factory productions.

Then came an extraordinary stimulus to the development of all these new inventions. The Civil War broke out, and shoes were needed by the armies in vast quantities, just at the moment when the industrial energies of the nation were dissipated in warfare. This gave the machine shoemakers their opportunity, and great factories, full of machinery, sprang up and absorbed and extended the manual crafts of the old shoemakers. The transformation of raw material into a finished shoe requires more than a hundred manipulations,

company occupies a unique position in our industrial system in that it does not usually sell its machines but merely leases them to the manufacturer on a royalty basis. It takes fifty-eight different machines to make a single shoe, and these are being constantly developed and improved by hundreds of highly skilled inventors employed solely for the purpose. To illustrate the thoroughness with which the American goes about his work, over one million dollars has been expended in developing one single machine — the al-



Courtesy Endicott Johnson Co.

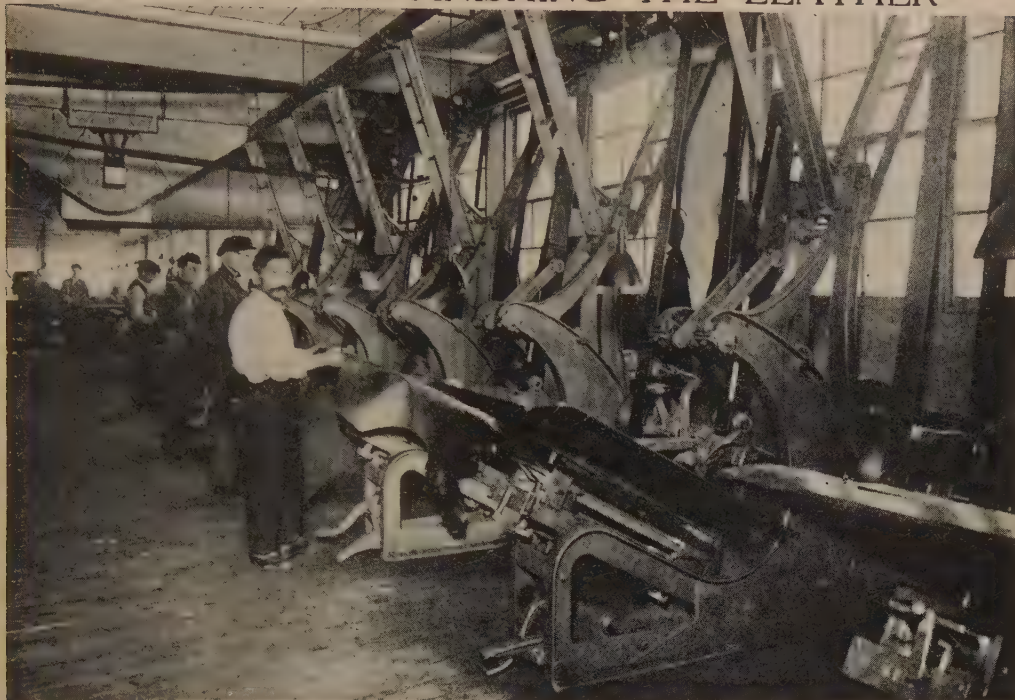
TAKING THE ROUGH SURFACE FROM LEATHER BY HAND

but our ingenious inventors at last succeeded in devising machinery to perform practically all of these operations.

Ancient methods gave place to this marvelous system of machines turning out perfect shoes by the hundred in the time formerly taken by the old-style workman to imperfectly make a single pair. At first the machines for the different operations were made by different concerns, but in 1899 several of them were consolidated into one big corporation, the United Shoe Machinery Company, the largest institution of its kind in the world. This

most human mechanism that pulls over the upper on the last, in the operation of last-ing. Practically all shoe manufacturers in America lease their machinery, and generally prefer to do so on account of the cost, and the rapid developments which often render a machine obsolete in a comparatively short time. Every shoe factory in Europe a few years ago was equipped with machines made abroad, which they owned outright. The majority of them are now equipped with American machines, leased on substantially the same terms as those which prevail in the United States.

GLAZING AND FINISHING THE LEATHER



THE GLAZING MACHINES WHICH GIVE THE LEATHER ITS GLOSS



Courtesy Endicott Johnson Co.

ONE OF THE LAST STEPS — PUTTING THE BLACK FINISH ON A SIDE OF LEATHER

America now makes the best shoes in the world. Europe is coming along fast, however, but it is only by putting in American machinery that she is able to compete with American shoes in style and quality. Massachusetts leads the United States in shoemaking, while Missouri comes next. Our home consumption is two hundred and seventy million pairs a year — three pairs to a person. Our exports of shoes have gone from \$4,000,000 in 1900 to over \$25,000,000 at the present time.

In making shoes a great variety of leathers is used, including alligator, lizard,

formed with unvarying accuracy. When an order is received in any well-organized factory of today, detailed instructions affecting the preparation of the shoe are sent to three different departments — the cutting room, where the material for the uppers is prepared, the sole-leather room, where the soles and heels are cut out, and the bottoming room, where all these different parts are assembled in the making or bottoming process. In the cutting room, after the kind of leather, linings, stays, etc., required are decided on, the leather is sent to a machine which cuts out



Courtesy Endicott Johnson Co.

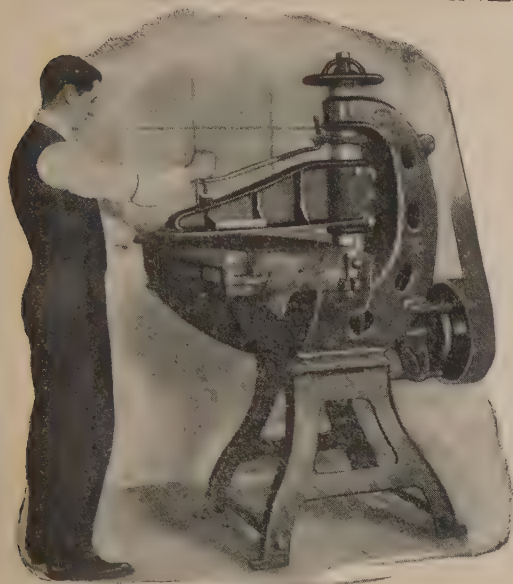
THE MACHINE FOR CUTTING OUT THE SOLES

snake and monkey skins, as well as the more common suede, moose, buckskin, deer-skin and patent or enameled leathers. These may be colored according to the demands of fashion, or the purposes for which they are intended. Cloth is also used for shoes and slippers.

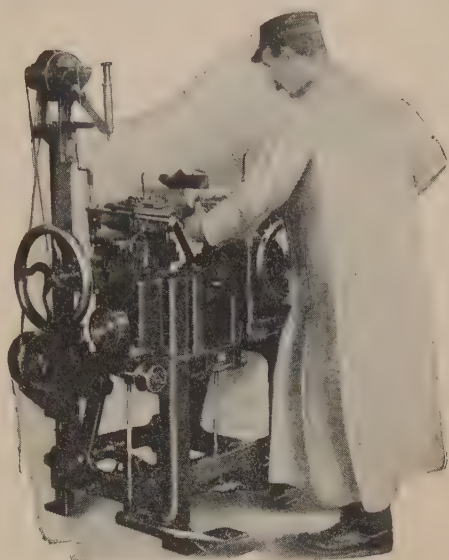
The evolution of the shoe in the modern American factory from mere leather and thread to the wonderful product which has contributed so much to the comfort of the world, presents a most interesting study. In many instances a single shoe passes through as many as 210 pairs of hands and 170 machine operations, per-

dies with all the differently shaped and sized pieces for the upper of the shoe, and marks the vamps for the location of the tip and the foxings, a most important operation. The parts are then passed on to other machines which bevel some of the edges which are to show in the finished shoe, and punch the ornamental perforations along the edge of the toe cap. After the linings are ready, they and the various parts of the shoe are sent to the stitchers, where the different parts of the uppers are united. This work is accomplished on a range of wonderful machines which do the work with great rapidity and accuracy.

REMARKABLE MACHINES REPLACE HANDWORK



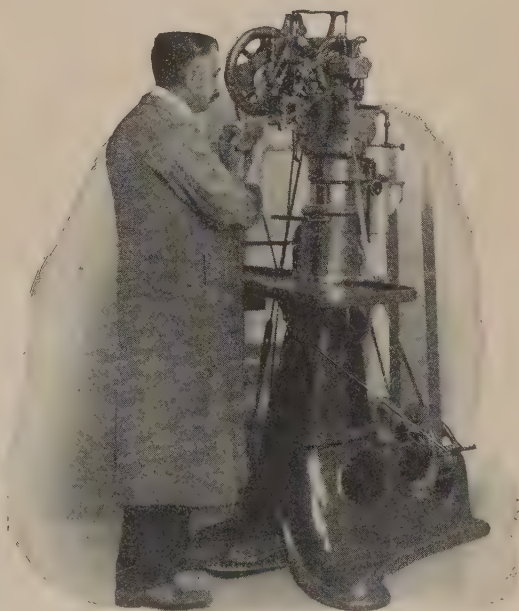
THE MACHINE THAT CUTS OUT THE UPPERS



THE LASTING MACHINE



THE PULLING OVER MACHINE



THE MACHINE THAT SEWS IN THE WELTS

From photographs loaned by the United Shoe Machinery Co.

After receiving the eyelets the upper is ready and is sent to the bottoming room to await the coming of the parts of the shoe which have been preparing in the sole-leather room.

Here the soles have been cut out by powerful machines which force dies of the required shape through the thick sides of leather, and have been submitted to tons of pressure between heavy rolls, and reduced by machinery to an even thickness. The insoles, counters, toe boxes and heels having been prepared by another series of ingenious machines, the different parts

to remove irregularities, the shoe is now nearing completion. The soles and heels are stained and given a high gloss, and the entire shoe brought to the required finish by various polishing and buffing devices. All this time the last over which the shoe was drawn early in the making process has been allowed to remain, so that the finished shoe, having acquired, may retain exactly the shape desired. The last is now withdrawn, and after a few minor operations the shoe is packed in cartons and is ready for the wearer. In every part of the world where shoes are made this



Courtesy Endicott Johnson Co.

STITCHING ROOM WHERE THE DIFFERENT PARTS OF THE UPPERS ARE SEWED TOGETHER

of the shoe now begin to meet in the bottoming room. Special machines assemble the parts into the exact position for lasting, a most difficult process which is performed by a machine almost human in the way it accomplishes its task. The shoe next receives the welt, a narrow strip of prepared leather that is sewed along the edge of the sole. The remarkable machine which stitches the welt, the upper and the sole together has been the leading factor in the great revolution which has taken place in shoe manufacturing.

After receiving the heel and after operations of trimming, rounding and leveling,

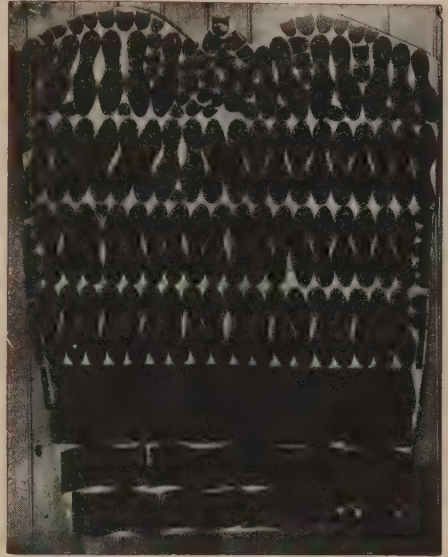
same process and the same machines are employed, varying only in unimportant details.

The result of our early control of the industry was that the poor in America were provided with cheap and good shoes long before the similar class in other countries were able to afford them. In ancient Egypt the rank of a person could be at once recognized by observing the way he was shod. The nobility wore shoes embroidered with gold and studded with gems, and each descending class indicated its social rank by the material of its footwear. Indeed it was prescribed by law.

Until a few years ago the shoes worn by the different classes in our modern society were almost as significant of the social positions of the wearers as were those of the ancient Egyptians. In the United States, however, shoe-machinery and chemical tannage of leather gave a democratically uniform appearance to the feet of the people.

Armed with labor-saving and labor-cheapening machines and his new chemical processes of leather-making, the American sailed across the Atlantic bent on supplying Europe with his well-shaped and smart-looking shoes. Instead of producing a few stock sizes, as was the custom of European manufacturers, he used pattern lasts for practically every shape of foot. Small variations in width and length, and combinations of these variations, enabled him to fit every customer with a cheap shoe that was almost as well molded upon the foot as if it had been hand-made to measure. American boots and shoes ousted the plain and cumbersome product of foreign designers and manufacturers who were not able to withstand the invasion. Thus the shoe trade of Europe was revolutionized by American inventive genius; although, due in great measure to further improvements of tanning processes by English scientists, the industry in Great Britain has also undergone a remarkable development from within.

Originally the small tanners depended for hides upon the surrounding country, but with the advent of the railroad and the steamship, and the application of chemical science, the tanner of today is dependent



A TANNED SKIN CUT UP FOR SHOES

There is no waste in the boot and shoe industry; every fragment left between the shapes cut out is used in making up the heels or is worked up into a composition.

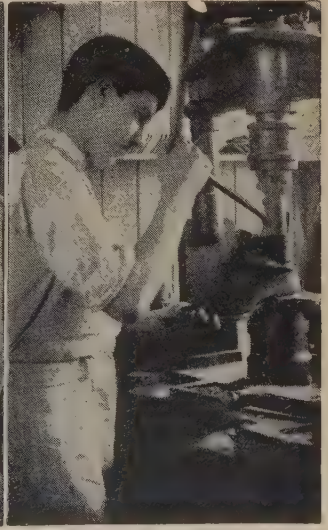
upon no one country nor any special animal for his raw material. The heavy hides are obtained from oxen, cows and horses, while the lighter ones come from calves, sheep, goats, deer, pigs, seals and from various fur-bearing animals whose pelts usually retain their hair after tanning.



ATTACHING THE SOLES



STITCHING ON THE SOLES



FIXING ON THE HEELS

In America the small hides of the cattle of our western plains make much stronger leather than do the hides of the big beefy cattle of the East. The skins of our mountain sheep and of the sheep of the Patagonian uplands of South America also are thicker than those of woollier and more carefully tended flocks. In Europe the cattle of the Bavarian uplands and the Pyrenees produce the finest hides; and it is from the unsheltered goats roaming the Saxon highlands and the Alps and the Pyrenees that skins of the lightest and yet toughest grain are obtained.

In regard to our shoemaking trade, the United States annually imports large quantities of the kips of yearling cattle of for-

The imitation grained leathers made from sheepskin are among the most perishable products of the modern tanyard. If the scientific tanner devoted himself seriously to the task of making a leather from the pelt of the sheep, in which the natural qualities of the skin were retained, the so-called kid boots and the so-called kid gloves of the cheaper sort would wear three or four times longer than they now do.

We do not now depend so much on leather as men did in primitive and barbaric ages. To various savages there is still nothing like leather. Of cured skins they make the tents in which they live, the shields wherewith they fight, the clothes they wear, and sometimes, as with our an-



FINAL OPERATIONS IN SHOEMAKING—



TRIMMING AND SCOURING THE SOLES

eign countries. A kip, we may explain, is merely the hide of a young beast. Taken from small, young cattle, and tanned by the chrome process, the kips make excellent material for the uppers of men's shoes. Many of the kid boots of women, on the other hand, are now made from sheepskin, which, when tanned with chromium, produces a passable imitation of glazed kid. Very little sheepskin is nowadays sold as sheep leather, though sheep leather, when properly made, is very durable and flexible. But somehow it has gone out of fashion. So the tanner converts it into various imitations of other leathers. Even the innocent little lamb masquerades as a kid in the modern leather industry.

cestors, their drinking-vessels are made of skin, their armor of hard leather, and their shoes of softer leather. We have gradually found better materials for many of these things. Yet leather belting is often necessary in our latest machinery. The small leather bag has freed women from the necessity of having pockets in their dresses. With increasing luxury, the glove, that is useful in winter, has become a social token to be worn, or at least displayed, on the hottest summer day. The automobilist and aviator have brought back the leather dress of our primitive forefathers, and the high-class motor-car is upholstered in leather, as is also a considerable amount of modern furniture.

PIONEERS IV

HORACE MANN—TO WHOM WE OWE THE
FREE PUBLIC SCHOOL SYSTEM IN
AMERICA

KARL MARX—THE ECONOMIST OF MOD-
ERN SOCIALISM

HORACE MANN

To Whom We Owe the Free Public School System

HORACE MANN, a distinguished American educational reformer, philanthropist and publicist, was born at Franklin, Massachusetts, May 4, 1796. While Horace Mann was not a professional educator, but rather a statesman and a publicist, he has aptly been termed the founder of the present American common school system, and certainly no educational leader in the United States has been responsible for more reforms in elementary education, and certainly no individual has been more widely discussed and his writings studied. He was the son of a farmer of limited means, and secured his early education in spite of great difficulties and scant opportunities. As a child he worked at braiding straw to earn money to buy his school books and from the age of ten to twenty years he rarely was at school more than six weeks. However, in this way he developed thrift and self-reliance, and was able fully to appreciate his advantages when he entered Brown University, from which institution he was graduated in 1819. He remained at Brown as teacher of Latin and Greek for two years before deciding to take up the study of law. Then, in 1821, he entered the Litchfield, Connecticut, Law School and was admitted to the Norfolk County bar in Massachusetts in 1823, opening an office at Dedham.

His interest in public affairs and measures for the betterment of the condition of the people openly manifested led to his election to the state legislature of Massachusetts in 1827, and here he was active in

MARIA MONTESSORI—AND EDUCATION
THROUGH THE SENSES

FLORENCE NIGHTINGALE—THE PIONEER
OF SCIENTIFIC NURSING

ROBERT OWEN—FOE OF CHILD LABOR

advocating measures in the interest of education, public charities and for the suppression of intemperance and lotteries. He was elected to the state senate in 1833, and became its presiding officer in 1836.

The most important event in his legislative career was securing the passage of an act creating a state board of education with the object of revising the school laws and reorganizing the common school system of the state. This was practically necessary as the development of the district school system and the growth of the large number of private schools in the commonwealth had in many ways impaired the efficiency and influence of the public schools, so that reforms were seriously needed. This act of the legislature not only provided for a board of education but for a secretary whose duty it was to exercise a general authority over the schools of the commonwealth. This position Horace Mann was induced to accept and he forsook the practice of the law to work on the reorganization of the Massachusetts schools. It might be said in passing that his career at the bar had been marked by unusual integrity and self-sacrifice, as he had the reputation of always satisfying himself of the justice of any cause which he undertook, and much of his work was done in the interests of those who were suffering from some form of imposition.

His first work with the Massachusetts Board of Education was to arouse throughout the state a general interest in the schools by means of lectures and public meetings. The lecture or lyceum system was then beginning to flourish in New England and through competent speakers,

INCLUDING SOME OF THE FORERUNNERS OF KNOWLEDGE AND PROGRESS

who were as ready to speak as large audiences were to hear them, it was possible to awaken the interest of many communities in various important problems of education and philanthropy. The board worked among the people at large, and their feelings once aroused, it was possible to secure the enactment of legislation which led to the reestablishment of a complete common school system, well organized and capable of far greater efficiency. Horace Mann's next move was to improve methods of instruction and raise the standard of the teaching force by establishing teachers' institutes and state normal schools. For the former he secured as lecturers the best available teachers of the subjects taught in the common schools, and of the art of teaching as then practised in the best schools. Three normal schools were organized, at Lexington (later Framingham), Barre (later Westfield), and at Bridgewater before the end of his third year of service.

In his very effective efforts to arouse the interest of the public and the legislators in the needs of the school Horace Mann collected and diffused information summarizing actual conditions of public education as carried on in the Commonwealth. By a law passed in 1826 the school committees in the various towns of the state were required to make annual returns of the school attendance, expenditures, etc., but no special use had been made of these records until Horace Mann employed them as a framework of a number of notable reports which became powerful engines in educating the public. As secretary of the Board of Education he prepared twelve annual reports which were more than mere official summaries, inasmuch as they dealt with live educational questions of general as well as local importance. In fact, the twelve volumes of the "Reports", published from 1837 to 1848, long have been considered educational classics, and soon after they appeared were reprinted for use in other states as well as translated for reference in Europe. Believing that the broadest currency should be given to his ideas and proposals Horace Mann also founded and edited *The Common School Journal* which had a wide circulation.

In these twelve reports referred to there was hardly a subject connected with elementary and secondary education that was not discussed in plain and certain terms. Each report was complete in itself, though it often covered a group of allied subjects, and, as stated, they dealt with general conditions as well as those encountered in the Commonwealth of Massachusetts. In his first reports Horace Mann discussed not only the physical factors and equipment of the schools but also matters of a pedagogical nature. He favored the word method of teaching reading as against the alphabetical method, and vigorously opposed the district system of school organization. His fifth annual report, for example, was virtually a pedagogical treatise which discussed the teacher, his or her training, pedagogical books, school management, corporal punishment (which he opposed vigorously), the relation of the state to education, and similar subjects. In another report courses of study are dealt with, particularly those prevailing, and the need for their enrichment. Horace Mann here advocates and discusses the educational value of the study of physiology and hygiene. *

In 1843 Mann made a trip to Europe to investigate and study educational conditions in various foreign countries and the results of this trip are incorporated in his seventh annual report which aroused a controversy and led to attacks on the reform by many teachers, particularly those in the Boston schools. His praise of European schools and methods was distinctly distasteful to many of the old line teachers, and severe criticisms of his observations were published in pamphlets and elsewhere. These naturally met with a defense from equally interested sources; the resulting controversy, however, proved of assistance to Mann and the course of educational reform by arousing a general public interest, and made him a popular as well as an educational figure. The theories advocated, notwithstanding the opposition, gradually triumphed and Mann's fame, despite bitter criticism, extended over the entire United States.

In his eighth report Horace Mann discussed the value of local and county educational sources, the value of vocal music in the elementary schools and the use of the Bible in the schools, while in his ninth he urged the employment of women teachers in the primary schools, emphasized the value of teachers' institutes and discussed the place of moral instruction in public education. The tenth report was a history of the Massachusetts school system, and the eleventh discussed the relation of education to crime. In his final report, written after his retirement from active duties as secretary of the Board of Education, Mann considers in some detail the changes of twelve years in education in Massachusetts, and discusses the problem of the education of defective and dependent children, which, with the growth of philanthropy, then was beginning to attract wide attention. Many of the reforms advocated were not effective during his incumbency of office, but his influence was felt and gradually they came into effect.

In addition to his educational work Horace Mann was prominent in other fields of public life. He was a vigorous anti-slavery advocate; in 1848 was elected a member of Congress from Massachusetts to complete the term of John Quincy Adams. While in Congress he was in controversy in regard to the extension of slavery and the fugitive slave law, and when a candidate for renomination he was defeated in the nomination by Webster supporters, but running as an independent anti-slavery candidate, was reelected. In 1852 he was nominated as a candidate for governor by the Free Soil Party in Massachusetts, but was not elected, and in the same year was selected to be the first president of Antioch College at Yellow Springs, Ohio, a position he held until his death on August 2, 1859. While his work at this new institution with its limited resources was attended by considerable difficulty, nevertheless he was able to carry into effect a number of his educational ideas and reforms and demonstrated the practicability of co-education in a higher institution of learning.

KARL MARX

The Economist of Modern Socialism

KARL MARX, the thinker who laid the more solid foundations of modern socialism, was, like his co-worker Ferdinand Lassalle, of Jewish origin, and, again like him, sprang from a well-to-do stock. His father was a lawyer named, not Marx, but Mordechai, and the son was expected to join the same profession after an education at Bonn and Berlin. He had been born at Treves on May 5, 1818. His taste did not, however, accept the law, and at the age of twenty-four he was embarked on the career of journalism as editor of the socialistic *Rheinische Zeitung*. Later he was connected with *Vorwärts*, an organ that has played a conspicuous part in socialistic agitation in Germany. By the time that he was thirty-one, Marx had made the Continent too hot to hold him. He had been expelled from France, Belgium and Germany, and sought a refuge in England, the asylum of contentious causes, and he lived in London for thirty-four years, till his death on March 14, 1883.

Before going to England he had organized, in Brussels, the Communistic League; and while in England he founded the "International", or International Workingmen's Association, an organization that passed through interesting vicissitudes, including a period of very considerable influence, but lost its importance when it fell into the hands of the anarchist section under Bakunin. The Marxist wing developed into Social Democratic parties in Germany and other countries.

Karl Marx was unquestionably the man of greatest intellectual weight who has associated himself with the socialist propaganda, and his writing, concentrated in the book "*Das Kapital*", has had a very far-reaching and profound effect on working-class thought in many countries. It is the Bible of the intelligent socialistic working man. He knows it thought by thought, to the undoing of opponents who talk at large, without that special study of economics which shows the limitations of the theories of Marx.

A most important feature of the writing of Marx is that it is much more than political and social economy in the eyes of those who believe. It is a religion and a prophecy — Marx reared his economic edifice on a foundation of history — the history that regards the story of man as a scientific evolution. He argued that the story of modern capital, and its command over men and the world, begins with the sixteenth century, and has had clearly traceable evolutionary phases. It has grown through conditions that came into existence unrealized at first; it has culminated in great wealth for the comparatively unproductive few, and poverty and anxious strain for the productive many, and it is moving on, inevitably, to a catastrophic overthrow. Evolutionary laws, as certain as the rising of tomorrow's sun, will destroy the present economic system, and usher in a new kingdom, wherein economic processes will be carried on, for the good of all, by the state. In those days governments will no longer be concerned in keeping the people who labor in subjection, but will control all labor and will insure that it reaps its just reward. Such a gospel as this is more than a dry economy. It is accepted as an inspiration and a hope. Its significance extends far beyond material things, for Marx believed that economic conditions supply the nurture for all human developments; and the life of man would be broadened and ennobled by the success of the ideas which he formulated.

It does not concern us here to examine the Marxian conception of capital — a conception that admittedly is so narrowed as to make it little except a cruel oppressor, "that comes dripping from head to foot, at every pore, with blood and dirt" — but no one who is unacquainted with the book can pretend to have a command of the essentials in the most vital economic controversies of our age. Like all prophets who try to foretell human evolution, Marx has been proved wrong in some respects by the inexorable logic of events, but far oftener he has been proved right, and has forecast many of the problems that have arisen in our economic life.

MARIA MONTESSORI

Advocate of Self-Education through the Senses

DR. MARIA MONTESSORI, who founded a new system for the education of the very young, was the first woman to take the degree of doctor of medicine at the University of Rome. At the time when she took the degree she was acting as an assistant doctor at the psychiatric clinic of her university. Dr. Montessori's interest in education began with the treatment of the feeble-minded, a problem to which she devoted years of special study. Her attention was arrested by Séguin's "Idiocy and its Treatment by the Physiological Method", and after translating the book into Italian she went to Paris and investigated the method in use there at the Bicêtre. Returning to Italy, she lectured in Turin and Rome on the education of defectives, and in 1898 was appointed directress of a school established to carry out her ideas — the *Scuola Ortofrenica*, or mind-straightening school. The results of her system were most remarkable. The progress of the children, all very dull and backward, was such that it admittedly made in some respects a favorable comparison with the progress of even bright scholars in the ordinary schools.

Dr. Montessori was herself so impressed that she resolved to concentrate herself afresh on the development of her system, and to that end she returned to the University of Rome for seven years as a student of psychology in special relation to educational methods. At the close of this period she was prepared to apply her own system to the average child. In furtherance of this plan, in 1907 and 1908 four infant-schools were established in Rome for the education of the children living in certain blocks of model tenement houses that had been erected there. The age of the children admitted to these *Case dei Bambini* (children's houses) was from three to seven, and the education was free.

Here the system achieved such a success as an experiment among the children of the poor that it was adopted for middle-

class districts, and it has spread to various European countries, and has been welcomed specially, as all educational experiments are, in the United States. In southern Switzerland it has become so popular that more than seventy schools have been established in the Canton Ticino alone, and her book on *Il Metodo della Pedagogia Scientifica* has been translated into thirteen languages.

The principle underlying it is that of self-education. The child is all the while finding out things for itself. This it does in play, but play that is skilfully directed, the objects with which the play is carried on being made and chosen for educative purposes which the child does not realize. There are no classes, no set lessons, but each child pleases itself. While doing so, however, it is unconsciously, and without strain or effort, learning; and at last — and, indeed, in a very short time — its play has resulted in its being able to write, to read and to understand simple arithmetic. Its reward is in a sense of discovery and mastery, through its own investigations, the teacher giving each child, individually, hints that help.

The method is by a gradual training of the senses. First, the sense of touch is developed. This sense in the child is keen and easily improved. Roughness and smoothness are first taught by passing the fingers lightly over rough and smooth objects carefully chosen. The child is led to distinguish, when blindfolded, textures, and differences in weight and size — a game that excites general interest. The names of the things are pronounced as they are learned by touch. Next form is taught, touch and sight coöperating. In this way the shapes of the letters are learned. Colors are next distinguished and graded. Hearing is also carefully trained. The deft use of the fingers follows, as in tying and untying bows, fastening and unfastening buttons.

Coloring geometrical forms follows, and the penciling of outlines — the prepared apparatus making success easy. In this way writing comes with remarkable quickness. In six weeks a child of four can be taught to write, and an ordinary child of

five in a month. In three months the child will write a good hand. The sounds of the letters and their combinations are learned, and reading follows naturally — in the case of phonetic Italian in a few weeks sometimes, in a few months almost invariably, while the child has only been playing an interesting game.

By similar apparatus the simple numbers and proportions in arithmetic are learned. Lessons are brief, and each child can change what it is doing whenever it wishes to change. Liberty is the basis of discipline — self-discipline — in the Children's Houses. There is no enforced discipline. Spontaneous activity in the child is respected, used and never suppressed, unless it involves interference with the liberty of others doing what they please. Dr. Montessori regards self-activity as the basis of discipline. The child not only acquires new capacities by doing, but also attains the necessary self-control and discipline.

That the method is successful in the case of defectives, and with very young children whose mental powers are undeveloped, has been abundantly proved where the supervision has been skilful and the use of the graduated apparatus fully understood, but less success seems to have been secured when the children come from middle-class homes, are more self-conscious and less easily amused; and further, it is not at all clear how far the method is applicable to children beyond their earlier years who need a wider education. The system is founded on Séguin's experiments. To a considerable extent it follows the plans elaborated by Froebel and his successors. It must not be forgotten that individual acquisition has been allowed free play in many of the best modern schools before Madame Montessori. Still, she has done education excellent service by the freshness she has imparted to child study, and she takes an honorable place in the true succession of educational pioneers.

She became director of the Montessori Institute founded in Barcelona in 1917, but continued to give training courses and lectures in all the principal European cities.

FLORENCE NIGHTINGALE
The Pioneer of Scientific Nursing

FLORENCE NIGHTINGALE, pre-eminently distinguished as the reformer of hospital administration and the initiator of the scientific nursing movement, was born at Florence, Italy, May 15, 1820. She was named after her birthplace, but her early years were mostly spent in England, her father's home. With brilliant attainments, and admirably qualified to shine in society, she chose to devote herself to the alleviation of suffering.

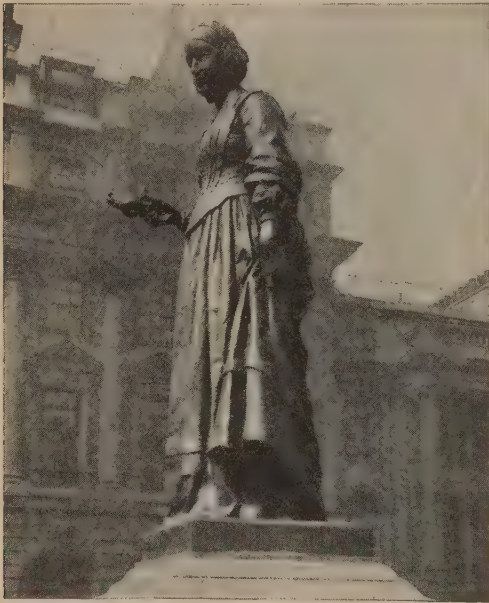


Photo W. F. Mansell & Co.

FLORENCE NIGHTINGALE

Keeping this end in view, she visited and examined the civil and military hospitals at home and abroad. In 1851 she went through a strict course of training as a nurse in the Institute of Protestant Deaconesses at Kaiserswerth, on the Rhine. Afterwards she completed her studies by a careful observation of the methods of nursing and management pursued in the hospitals of Paris. At this period nursing in England was practised in a very haphazard fashion and when Miss Nightingale returned she undertook the thorough reorganization of the hospital for governesses in London.

In 1854 arose the great national emergency in which her practical skill was put to a supreme test. War was declared with Russia in the spring, but, owing to the flagrantly defective organization of the British army in the commissariat department, English soldiers underwent indescribable hardships. There were no ambulance-wagons, the sick and wounded were carried by sailors in hammocks or in ambulances borrowed from the French, and, to make matters still worse, the huge barrack hospital at Scutari was in a deplorable condition. In this crisis Miss Nightingale offered her services to the government, and on October 24 (the day before the battle of Balaclava) she departed with more than thirty nurses, and reached Scutari on the eve of the battle of Inkerman.

She found the wards overcrowded with patients, while hundreds of wounded were on their way. Miss Nightingale's work during that terrible winter made an ineffaceable impression on the imagination of the English race. Her self-devotion was extraordinary; she would stand for twenty hours at a stretch to insure that the wounded were properly cared for; and when at night, with lamp in hand, she made her round, the grateful soldiers would kiss the shadow of "the Lady with the Lamp" as she passed their beds.

Very soon 10,000 men in the hospitals on the Bosphorus were under Miss Nightingale's gentle and capable control; and the effect of her scientific administration was quickly seen in the fall of the death-rate. This had stood at the appalling figure of 42 per cent in February, 1855, but about the middle of the year it had diminished to 2 per cent. Part of her time was occupied in personally organizing the nursing arrangements at the Crimean camp, and while so engaged she herself was prostrated with fever. Still undaunted, she refused to quit her post, and after her recovery remained at Scutari until Turkey was evacuated by the British, in July, 1856. Her splendid self-sacrifice had won her the reverence and affection of the army, and the admiration and gratitude of the nation.

A man-of-war was sent by the government to bring Miss Nightingale, the first and only time such an honor has been accorded a woman, but she preferred to return quietly and avoid the great popular reception awaiting her in London. She reached her country home, broken in health, but, happily for the cause of sanitary reform, with a long life of service before her.

The sum of £50,000 was raised as a national gift, and with this Miss Nightingale founded the Nightingale Home for training a superior class of nurses at St. Thomas's and King's College hospitals. In 1857 she supplied "the Commissioners appointed to inquire into the regulations affecting the sanitary condition of the British Army" with extremely valuable evidence gathered from her Crimean experience, and emphasized the lessons deducible from the colossal experiment in sanitation which the war had necessitated, and she was often consulted on questions connected with camp hospitals during our Civil War and the Franco-Prussian War.

In 1858 she published her "Notes on Nursing", and in 1859 the "Notes on Hospitals". Both books are clearly and suggestively written, and, containing a wealth of practical details, they have proved of immense value to women students, as well as to men professionally concerned with the planning and construction of hospitals. She also wrote "Notes on Lying-In Institutions", and in 1873 "Life or Death in India".

The benevolent mission which Miss Nightingale so courageously fulfilled in Scutari and later at Balaclava was the beginning of a new era in hospital administration. Her contribution to human welfare was not limited to mitigating the evils of war by the impetus she gave to army reforms bearing on the treatment of the sick and wounded. Her own unselfish example stimulated ladies of her class to study the science of nursing, and to apply it to the needs of civil life. The whole character of nursing was revolutionized. The most striking outcome of Miss Nightingale's work was the institution of the Red Cross Society.

The freedom of the City of London was given to her in 1908. She had already received the Order of Merit, the first woman to be so honored, in 1907. She died on August 13, 1910, at the age of ninety. An interesting statue, lamp in hand, was erected at a busy corner in the West End of London to her memory in 1915 as part of the Crimean Memorial.

ROBERT OWEN

The First Opponent of Child Labor

ROBERT OWEN, social reformer, was born at Newtown, North Wales, on May 14, 1771; the son of a saddler. A bright boy, he was apprenticed at ten years of age to a draper and at nineteen became manager of a cotton mill at Manchester employing 500 hands. Owen quickly mastered the details of the business, increased its scope, and exercised a powerful influence over the workmen. He had already come to the conclusion that human character results from antecedents and surroundings, and argued that, given fair conditions and means of education, men would naturally become moral and useful citizens.

Owen was an admirable business man as well as a philanthropist; and when a change was made in the business, in which he had already been given an interest, he established, with other partners, a business of his own. During his travels he had met the daughter of David Dale, who had instituted at his New Lanark mills perhaps the first attempt at an industrial model village.

Two years before Owen became his son-in-law, Dale had his "little kingdom" of neat, well-built houses, forming broad, regular, and cleanly streets. "Five hundred children are entirely fed, clothed, and instructed at the expense of the venerable philanthropist," wrote a visitor at the time. "The rest of the children live with their parents, in comfortable and neat habitations in the town, and receive weekly wages for the labor. The lesser children, that are not old enough to work, are instructed in the daytime; the elder children learn in the evening, when the daily labor is concluded. The boys learn to read

and write and cast accounts; the girls, in addition to these, are taught to work at the needle." Without in any way detracting from the work achieved by Owen, we see here where, possibly, the germ of his ideas as to the education for the young was gained, and it should make us examine with care the statement that schools for infants originated with him.

The "five hundred children" mentioned in the statement were pauper children, taken from the workhouses and other public institutions, and, despite the care of their master, they were greatly overworked, and could not have been fit to receive instruction at night. Moreover, the adult workers, according to Owen, were drunken and riotous. It was not difficult to introduce improvements on what was, considering the state of public opinion at the time, a really considerable advance upon the conditions existing elsewhere.

Owen stopped the import of paupers; he improved the circumstances of the adults, both in regard to their life in the mill and in the home; started a coöperative store at which they could buy good food and other articles cheaply; inculcated sobriety and honesty, and, when cotton supplies temporarily ceased, paid the wages of all his hands for seven months. He instituted admirable schools, which took infants as soon as they could walk, and kept them up to the age of twelve, when, and not before, they were permitted to enter the mill.

Owen in 1812 published his notable "New View of Human Society", expounding his theories of character and education; and his mills, with their school and settlement, became a place of pilgrimage for social reformers. The outstanding feature of this part of his life was his attack upon the factory system in regard to child labor. Factories were unknown until Arkwright's day; the system had become widespread by the time Owen reached Scotland. The youngest children were hustled into steaming, unhealthy, ill-ventilated mills, and kept there as long as their masters chose to detain them. A new horror had come into child-life.

Owen urged upon Peel that no child should be admitted into a factory until ten years of age; that no child under the age of eighteen should be permitted to work more than ten and a half hours a day, and that instruction for children engaged in mills should be compulsory. The demands seem small as one reads, but, even so, they were whittled away by Peel under pressure from the manufacturers, until only the bald and unconvincing Factory Act of 1819 resulted. Still, it recognized as a principle for the first time that the state really owed a duty as guardian of the least mighty of its subjects.

Thereafter Owen, while he effected a fine work in the promotion of coöperation, was engaged in fruitless and visionary efforts to found ideal communistic colonies. He sought to effect, with promiscuously gathered assemblages of all sorts and conditions of men, the purpose which he had previously taught could only be gained by the training of the masses from childhood to morality, sobriety and all the duties of citizenship. He tried his scheme in the United States, in Mexico, in England, in Ireland, and it was in the end defeated, as from the very nature of the case was bound to happen. His uncompromising hostility to all orthodox religion did not help to make his path more smooth, but, strange to say, he ended by turning spiritualist. He died at his birthplace on November 19, 1858.

His son, Robert Dale Owen, was born in Glasgow, November 9, 1801. He came to the United States in 1825 to help his father found the socialistic community of New Harmony in Indiana. He became an American citizen and was elected in 1835 to the state legislature. In 1843 he was a member of Congress, and in his two terms took an important part in the settlement of the northwestern boundary and the Oregon question, and was instrumental in the founding of the Smithsonian Institution. He was our minister at Naples from 1853 to 1858. He served on the Ordinance Commission during the Civil War and wrote a number of books, several relating to spiritualism, in which he was a firm believer. He died on June 17, 1877.

